RHINE AND MEUSE

RIVERS

Ministerie van Verkeer en Waterstaat

Rijkswaterstaat

Keeping our feet dry, providing clean water for everyone, and ensuring a smooth and safe passage for shipping: these are the major objectives of the Directorate-General for Public Works and Water Management (Rijkswaterstaat) regarding the management of the River Rhine and the River Meuse.

This book gives an overview of present-day river management. Of course, other stakeholders are also concerned in ensuring a safe, clean and attractive river environment: these include municipalities, district water boards, provincial authorities, ministries, businesses, nature conservation organisations, and, last but not least, the local inhabitants.

The activities of RWS are closely related to the initiatives of these stakeholders, and therefore are an unmissable part of our society.

TWO RIVERS: RHINE AND MEUSE

Table of Contents

1 A swampy delta 5

2 Rhine and Meuse 9

3 Rivers in everyday life 21

4 Rivers of silt, sand and gravel 33

5 Floods 43

6 Low flows 59

7 Healthy rivers 67

8 New trends in river management 81

FOREWORD

Whenever I am in the river area I am struck by the beauty of the rivers as they flow through a landscape of floodplains and natural levees. A sentiment which is echoed in the beautifully-worded Dutch poem by H. Marsman: ‘Herinnering aan Holland’. Of course the rivers as they are today are largely the work of human beings. Hundreds of years ago, the people living in the Netherlands began to make the area inhabitable by building dykes, and so the Middle Ages saw the laying of the foundation for all the hydraulic works which would follow in the centuries to come. In more recent times we have come to value the natural environment in and around the rivers and we want to improve the quality of this nature.

A great number of experts have studied the rivers minutely. A quotation from the ‘Voorbericht’ [Foreword] of a committee in 1827 states: “…it is the considered opinion of all the experts that the condition of the rivers Rhine, Lek, Waal and Meuse from time to time so deteriorates that the adjoining lands are more and more threatened, so that it must be feared that an irreparable disaster at some point, sooner or later, cannot help but occur.” We did indeed experience this for ourselves during the floods of 1993 and 1995 when parts of Limburg were covered with water, and about 250,000 people had to be evacuated from the river area.

Periods of flooding are interspersed with periods of water shortages. In dry summers, such as those of 1976 and 2003, there was not enough water to supply both agricultural needs and cooling water for the power stations situated along the rivers.
And just what else does the future have in store for us? In the coming years we will be giving the rivers more space in order to increase safety. New nature areas are being established to strengthen the local ecology. But we must also anticipate more frequent occurrences of extremely high or low water levels in the rivers as a result of climate changes.

In this book we hope to share our fascination for the rivers with you. It describes the Rhine and Meuse rivers and the way in which we use them, and gives an overview of the most important developments and the work of Rijkswaterstaat. The book invites you to not just read about the rivers, but to go and visit them for yourself and also to to obtain more information from the other source materials which it refers to.

I hope you enjoy reading this book.

Gerard Blom, Head of the Rivers Department for
RIZA [the Institute for Inland Water Management and Waste Water Treatment]

1

A SWAMPY DELTA

Living in a delta means living with the dangers posed by water. But at the same time, it is the water itself that makes the delta so attractive. Thanks to water, the Netherlands is blessed with productive soils, transport facilities and sufficient drinking water, although we can never afford to become complacent.

Visiting the Netherlands in 42 A.D., the Roman author Pliny the Younger wrote: “A mud landscape where it is not clear whether the mud forms part of the land or the water. A miserable people live here in huts on hills that they have constructed with their bare hands. They resemble seafaring people when the water covers the surrounding area, although when the water recedes they are more like shipwrecked sailors.” Pliny found it incredible that our remote ancestors had the courage to live in such a boggy delta.
And now, about two thousand years later, the mud landscape has been changed into a prosperous land: Pliny’s ‘shipwrecked sailors’ and their descendants have reclaimed the swamp, tamed the rivers and won numerous victories over the sea. They have built dykes, storage basins, pumping-stations and storm-surge barriers to protect themselves from floods and to obtain land. They have constructed sluices, weirs, groynes and cut-off bends to enable them to navigate the rivers. And this is how they have managed to suppress the dangers of the delta and to take increasingly better advantage of its benefits.

However, despite all these efforts, the Netherlands is still to a great extent characterised by water. Our country has a surface area of 34,000 km^2. If there were no dykes or dunes, almost two-thirds of this would be inundated when the sea or the rivers are at high tide. It is this low-lying land that is the part of the country where most of the population lives and whose economic value is the highest. The lowest point - the Prins Alexanderpolder near Rotterdam – is situated as much as 6.76 metres below sea level. This is why present-day protection against flooding is also of vital importance and an essential condition for prosperity.

The importance of river water
Most of the fresh surface water in the Netherlands originates from the major rivers, with 65% of this water coming from the Rhine and 8% from the Meuse. The rest is derived from precipitation and a number of smaller rivers. This fresh water is used for a variety of purposes such as shipping, the production of drinking water, recreation, cooling water, agriculture, nature and industry. An ingenious system of weirs and sluices ensures that the fresh water is transported to all parts of the country and that the salt water is swilled away. When little fresh water is available after a long dry period, the most vulnerable functions are given priority. This will occur more frequently in the future due to climate change: more attention will have to be devoted to suppressing salination.

Rivers constitute a major shipping route between the seaport of Rotterdam and the hinterland. Since inland navigation is of considerable importance to the Dutch economy, a great deal of attention is given to maintaining safe and reliable waterways. One prerequisite is sufficient navigable depth, and to maintain this, the erosive force generated by rivers themselves is put into action wherever possible. If this force is insufficient, weirs and dredging are essential.

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The value of rivers is not only an economic one: many people enjoy living near a river landscape or spending their free time there. Riverside areas provide facilities for all kinds of recreation, such as walking, cycling, boat trips, painting, etc.

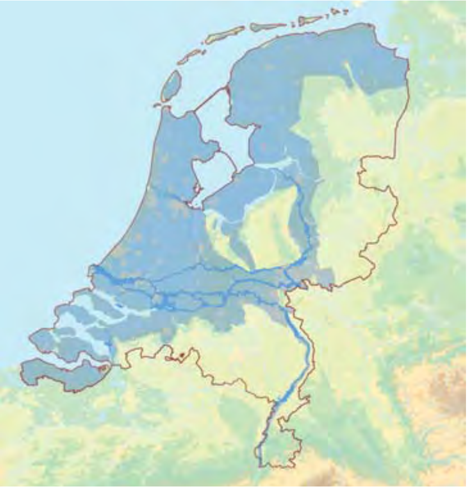
Cleaner, more natural and more spacious

In the 1970s, the water in our rivers was severely polluted, and a great deal of contaminated silt was deposited on the floodplains and riparian zones as a result. At the same time, the natural habitats of plants and animals native to riverside areas disappeared due to cut-off bends, development and agricultural use. Considerable efforts have been made since then to reduce pollution and to try and re-create these natural habitats. The results of this can now be seen: after a prolonged absence, various species of insects, fish, mammals and birds are returning to the rivers. European legislation has given a new incentive to nature conservation and restoration of the rivers, and has consolidated international collaboration in this regard.

Over the next few years the riverside areas will be the site of major refurbishment works. Climate change and rising sea levels mean that the rivers will need to be able to cope with an increased flow of water. Although the dykes will have to be heightened at a number of points, rivers will be given more space wherever possible. This extra space along the rivers will be partly designated as a scenic area, the idea being that this will benefit safety and riverine wildlife alike. With regard to safety, a European Directive will be drawn up during the next few years to foster international collaboration in catchment areas.

Co-existing with water

Water managers want to increase the involvement of citizens, administrators, stakeholders and businesses in the management of the major rivers during the years to come. These parties will be given the opportunity early on to contribute cooperative input on how their immediate living environment should be laid out. Water managers will be adapting their procedures to fit in with such ideas. One of the things our society sets great store by is the safeguarding and development of spatial quality when bringing about changes in riverside areas. Even now, improving spatial quality is often a second major objective following behind flood protection. And the government will be starting a discussion on safety policy: do Dutch people consider the current protection against flooding to be sufficient, or would it be advisable to approach the flood risk from another angle?



🟦 Part of the Netherlands which would be flooded without any protection by dunes or dykes

1 Erasmus Bridge over the Nieuwe Maas at Rotterdam **2** Cyclists on a dyke near Ooij
3 Orchard at the Betuwe **4** The Grensmaas **5** Weir at Hagestein

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RHINE AND MEUSE

By European standards, the Rhine and the Meuse are large to medium-sized rivers. People have been working to manipulate the courses of the rivers for centuries, and the natural riverside scenery has been gradually changed into a cultivated landscape. This landscape varies considerably in each section of the river.

RHINE AND MEUSE IN EUROPE

The Rhine

The Rhine is 1,320 kilometres long. The river starts its life in the glaciers of the Gotthard Massif as a swiftly-flowing mountain stream. Fed by rainwater and meltwater from seven countries, the Rhine subsequently makes its way to the North Sea. Its catchment basin has a surface area of 185,000 km^2, the largest part of which (160,000 km^2) is situated outside the Netherlands. An average of 2,300 m^3 water per second flows through the Rhine at Lobith (Gelderland). The only European rivers that transport more water on average are the Volga and the Danube.

The water of the Rhine mainly consists of meltwater derived from snow and glaciers until it arrives at Basle. At this part of the river, the water is usually at its highest level in spring and early summer, when the snow melts. Large tributaries join the Rhine when it gets to Germany, such as the Neckar, the Main and the Moselle. These tributaries transport a great deal of water, particularly in winter if there is heavy rain in the low mountain ranges in Germany. In the Netherlands, too, water transport from the Rhine is at its highest in winter. These two sources – meltwater and rain – ensure that the Rhine is navigable all year round.

The Meuse

The Meuse is 875 kilometres long. Its source is situated about 100 kilometres to the north-east of Dijon, at 409 metres above sea level. The river reaches the Netherlands at Eijsden, just south of Maastricht, via France and Belgium. Its catchment basin covers an area of 36,000 km^2, which is approximately the same area as that of the Netherlands. This is only one-sixth of the Rhine's catchment basin. The mean discharge of the Meuse is about 230 m^3/sec (measured at Borgharen, the Netherlands).

There are no high mountains in the Meuse's catchment area, which means that melted snow does not contribute to river discharge. The Meuse is fed entirely by rainwater: floods usually occurs in winter, and low water in the summer and autumn. Weirs have been constructed over a large part of the Meuse in order to ensure that the river is also deep enough to accommodate shipping throughout the summer.

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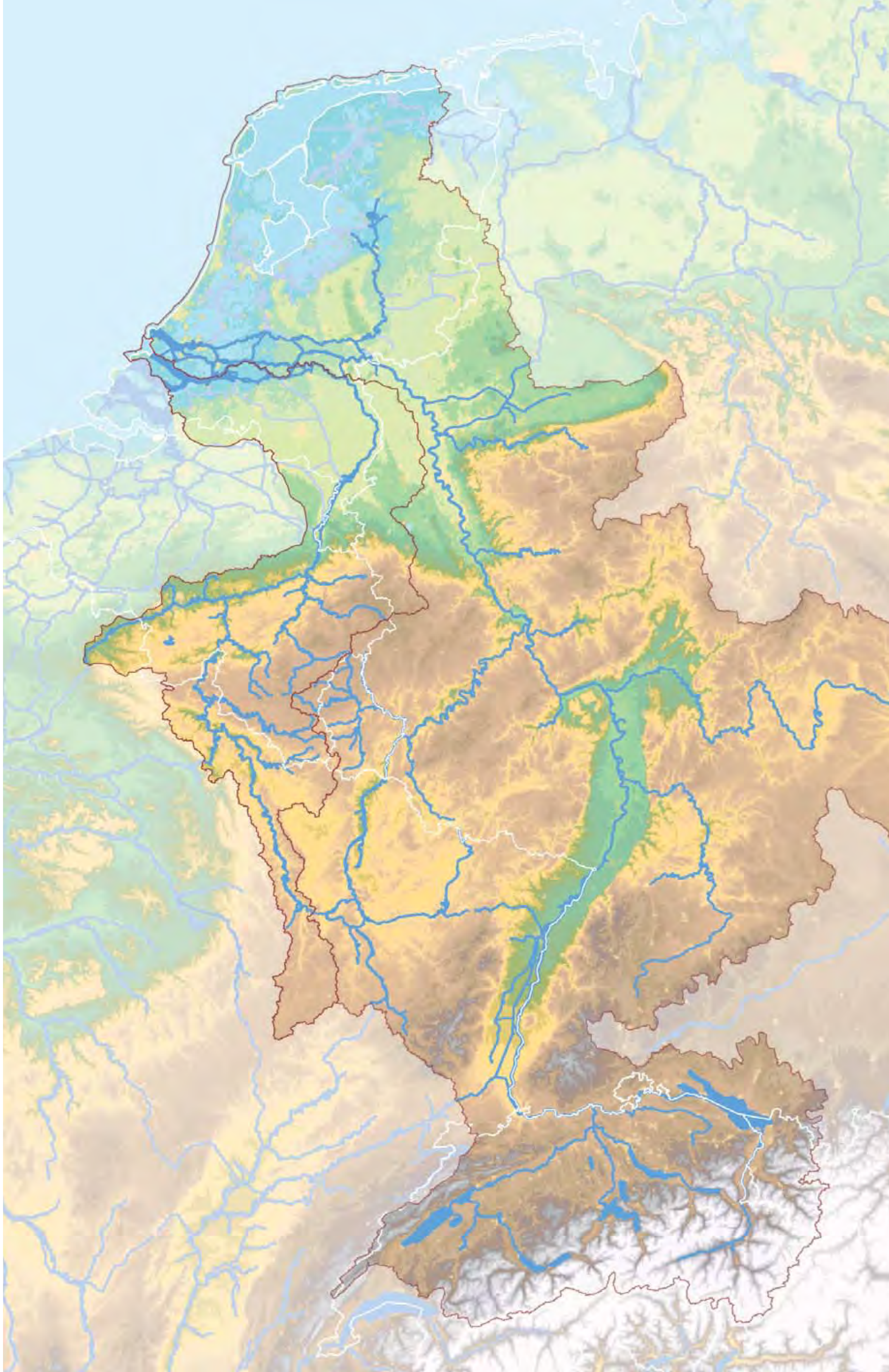
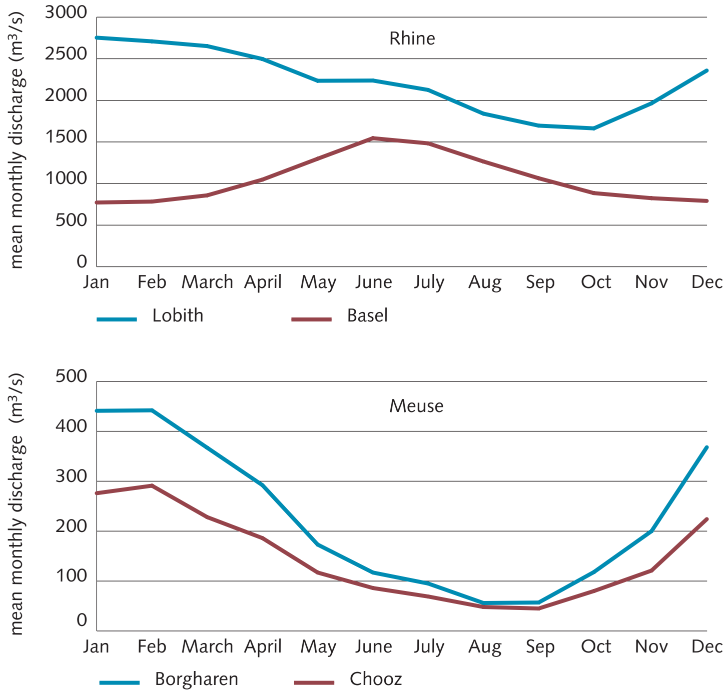
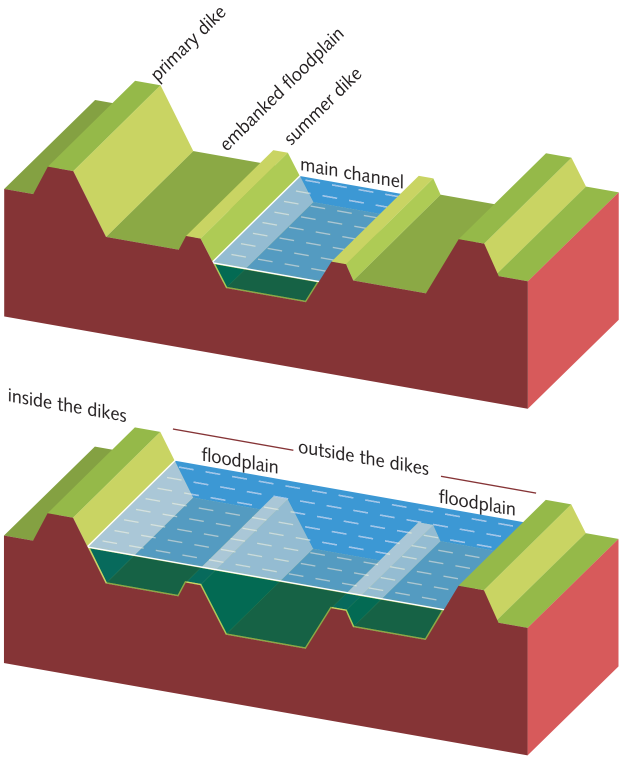




Discharge distribution for Rine and Meuse throughout the year. The Rhine is fed by rain- and melt water; During the summer melt water runoff causes great discharges at Basel. During the winter rainwater runoff from the German tributaries causes great discharges at Lobith. The Meuse is a rain-fed river with highest discharge in winter.



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	mean discharge on the debouchement (m^3/s)	*length (km)*	*surface area of the catchment (km^2)*	*number of countries*	*number of inhabitants in the catchment area*
Volga	8.500	3.660	1.380.000	3	61.000.000
Danube	6.500	2.960	817.000	10	80.000.000
Rhine[1]	2.200	1.320	185.000	9	55.000.000
Rhone	1.700	810	98.000	3	15.000.000
Dnjepr	1.600	2.285	503.000	3	33.000.000
Po	1.500	650	74.000	3	17.000.000
Vistula	1.100	1.064	194.000	5	27.000.000
Elbe	880	1.091	148.000	4	25.000.000
Don	870	1.970	422.000	2	22.000.000
Loire	850	1.100	120.000	1	11.500.000
Tagus	600	1.100	89.000	2	9.000.000
Oder	540	906	125.000	3	10.000.000
Seine	500	776	79.000	2	15.000.000
Douro	490	897	97.000	2	4.100.000
Ebro	430	928	86.000	3	2.800.000
Meuse[2]	230	875	36.000	3	8.800.000
Guadaquiver	230	666	58.000	1	4.000.000
Garonne	200	525	57.000	2	2.500.000
Guasiana	80	778	67.000	2	4.000.000

Large rivers in Europe

1 discharge at Lobith, size upstream catchment area 160.000 km^2

2 discharge at Borgharen, size upstream catchment area 21.000 km^2

RHINE AND MEUSE IN THE NETHERLANDS

The Dutch Rhine Tributaries

The Rhine delta begins in the Netherlands. The river divides into three tributaries just a few kilometres after crossing the border, starting with the Waal and Pannerdensch Kanaal at the Pannerdensche Kop. A few kilometres downstream, the Pannerdensch Kanaal flows into the Nederrijn, while the IJssel branches off from this river near Arnhem. Still more divisions, confluences and name changes occur in the neighbourhood of Dordrecht and Rotterdam. The water then flows into the North Sea through the Nieuwe Waterweg canal, as well as through the Haringvliet sluices at times of high discharges. A small part of the Rhine water flows into the sea through the Amsterdam-Rhine canal and the North Sea canal. The IJssel discharges itself into the Ketelmeer and subsequently into the IJsselmeer and the Wadden Sea.

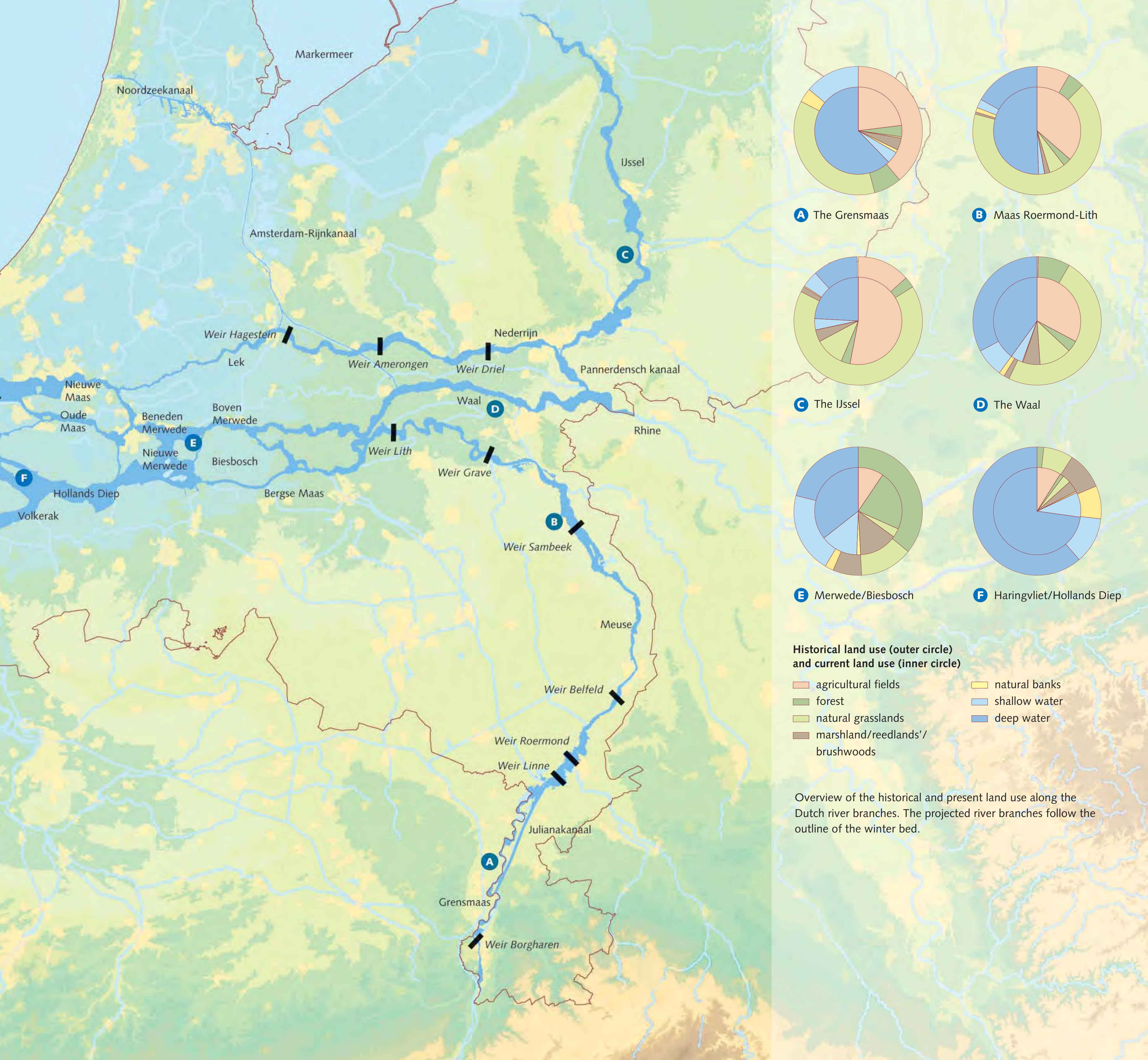
1 The catchments area for the rivers Rhine and Meuse
2 Cross-section of an embanked river with and without inundated floodplains

The three Rhine tributaries all differ considerably from one another. The Waal is the Netherlands' deepest and widest river. The river first meanders slightly through a landscape of natural levees and basins. The floodplains comprise meadows, agricultural fields, natural areas and lakes formed by sand-dredging works. The tidal zone becomes marked after Zaltbommel: here, we can see reed marshes, osier-thickets and mud flats in the floodplains. The natural levees along the river become smaller and the surrounding countryside more open. The Nederrijn-Lek does not always flow freely: at low water, the three weirs at Driel, Amerongen and Hagestein stem the water so as to allow shipping to proceed and to regulate the distribution of discharge. The river first flows past the high lateral moraine which was pushed out by ice caps during the Ice Age. Passing Amerongen, the river then flows into open country with small natural levees and extensive sedimentary basins on both sides. After the Hagestein weir, the Lek can flow freely and the tidal effect becomes perceptible. There are many historical buildings situated along the winding Lek dykes. Between Arnhem and Deventer, the IJssel flows through a small-scale, attractive rural landscape interspersed with mounds, meadows with pollard willows, hedgerows, wooded banks, picturesque old villages, parks and country estates. After Deventer, the character of the river and the surrounding country changes; the river does not wind so much and the floodplains are smaller, apart from those near the Duursche Waarden between Olst and Wijhe. Between Zwolle and the Ketelmeer lake, the IJssel bends twice before subsequently flowing into the wide-open delta area through an increasingly straighter riverbed. Due to land reclamation and re-allocation, much of the original character of the delta and surrounding area has been lost.

The Dutch Meuse

The Netherlands section of the Meuse is 250 kilometres long, and the river water drops about 45 metres over this

A Grensmaas **B** Bergse Maas **C** IJssel **D** Waal **E** Biesbosch
F Nieuwe Waterweg



Overview of the historical and present land use along the Dutch river branches. The projected river branches follow the outline of the winter bed.

distance. The southern part in particular has a much bigger fall than the Rhine. Weirs have been constructed along most of the Meuse to facilitate shipping; the only non-navigable part of this river is the southernmost part, the Grensmaas. Here, the Meuse meanders over shallow gravel banks; there are no weirs and the river flows swiftly at times of high discharge. Shipping goes along the Julianakanaal, which runs parallel to the Grensmaas. At Roermond, large lakes have been formed following gravel dredging. During the course of the years, the Meuse has cut increasingly deeper into the surrounding country between Cuijk and the Belgian border, resulting in a step-like terraced landscape in which the top terraces are the oldest river beds. This is a unique landscape by Dutch standards due to the vast differences in height. Old villages are situated at the transition point between low terraces and central terraces. No dykes are required here, since the banks are naturally high. Following the river downstream from Cuijk, the Meuse valley becomes a plain where both Meuse and Rhine have left sediment deposits. At this point, the river flows through high natural levees and low-laying sedimentary basins; this part of the river has been embanked. The major bed has levelled up rapidly since the dykes were constructed, so that the floodplains are currently situated at a much higher level than the surrounding area. The water pursues its course to the sea through the Bergsche Maas and the Nieuwe Waterweg; it also flows through the Haringvliet at times of high discharge.

The Rhine-Meuse estuary

Rhine and Meuse meet at the Rhine-Meuse estuary. Here, water levels are mainly determined by sea tides and to a considerably lesser extent by river discharge. Tidal influence runs through the entire course of the Nieuwe Waterweg. This influence is already noticeable in the river's downstream sections at Hagestein (Lek), Zaltbommel (Waal) and Lith (Meuse). At high tide, salt water enters the Nieuwe Waterweg, and travels as far as Dordrecht when the river discharge is low. If high sea tides coincide with low water discharges, this salt water can even reach the Haringvliet and the Hollandsch Diep.

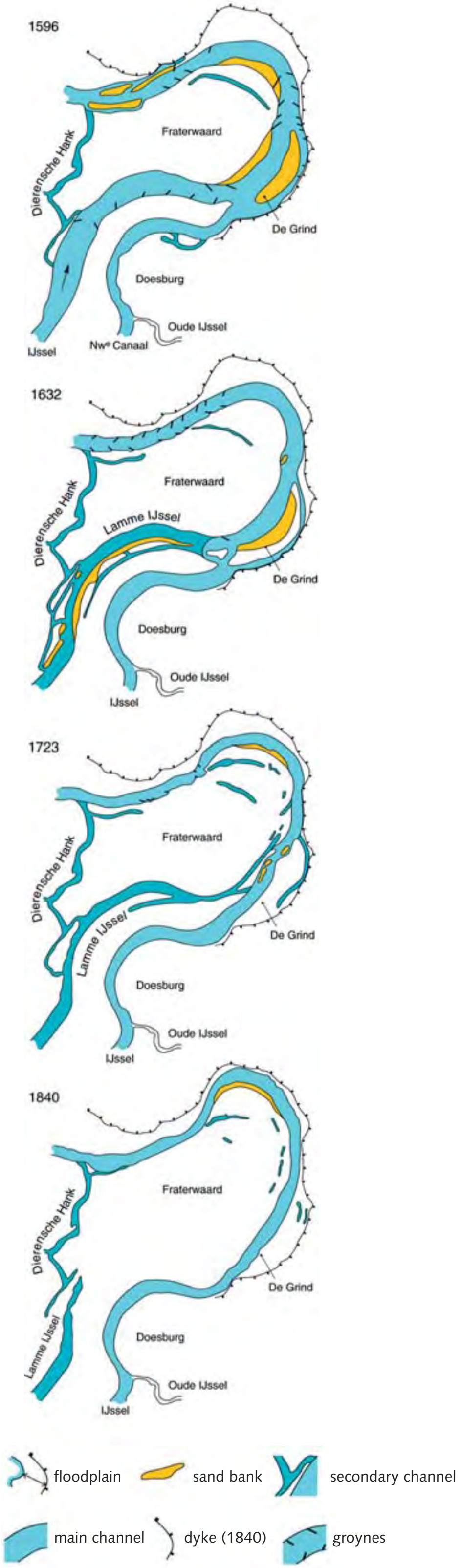
At the Rhine-Meuse estuary, the Haringvliet sluices constitute the regulating cock for the distribution of discharge among the various tributaries. During times of average discharge, most of the river water flows to the sea through the Nieuwe Waterweg. A small part flows into the sea via the Haringvliet, where the river water reaches the North Sea at low tide through the 17 discharge sluices in the Haringvliet dam. When discharge is high, the sluices open still wider, and more river water ultimately flows out through the Haringvliet than through the Nieuwe Waterweg. With a Rhine discharge of approximately 9000 m^3/s, the sluices are completely open at low tide, while at high tide, they are always closed to prevent salt water from flowing into the Haringvliet.

This transition area from river to sea consists of a tangle of watercourses. At low tide, the small banks, with their characteristic reed lands, are dry. The Biesbosch used to be a unique freshwater tidal area, but these tides have largely disappeared since the damming of Haringvliet and Hollandsch Diep. Despite this, it is still an attractive area with its mud flats, salt marshes, creeks, osier thickets, embankments, agricultural polders and riparian woodlands. The waters of the Rhine-Meuse estuary flow through low-lying country that is sometimes way below sea level.

HEAVILY MODIFIED RIVERS

Period before 1600

Taming the major rivers started as early as the time of the Romans. In about 10 B.C., the Roman commander Drusus constructed Drusus's Dam in the Upper Rhine to allow more water to flow through the Nederrijn. This afforded the Batavians better protection against the Germanic tribes. The very first dykes in the riverside areas of the present-day Netherlands were constructed in the tenth century A.D. These small dykes were built at right angles to the river and ensured that the surplus rainwater and river water flowed into the wide main channel. Large-scale damming of the rivers did not start until the twelfth and thirteenth centuries, when the first drainage basins were put into operation. The major rivers were almost entirely embanked in the fourteenth century, although the dykes did not prevent all flooding.



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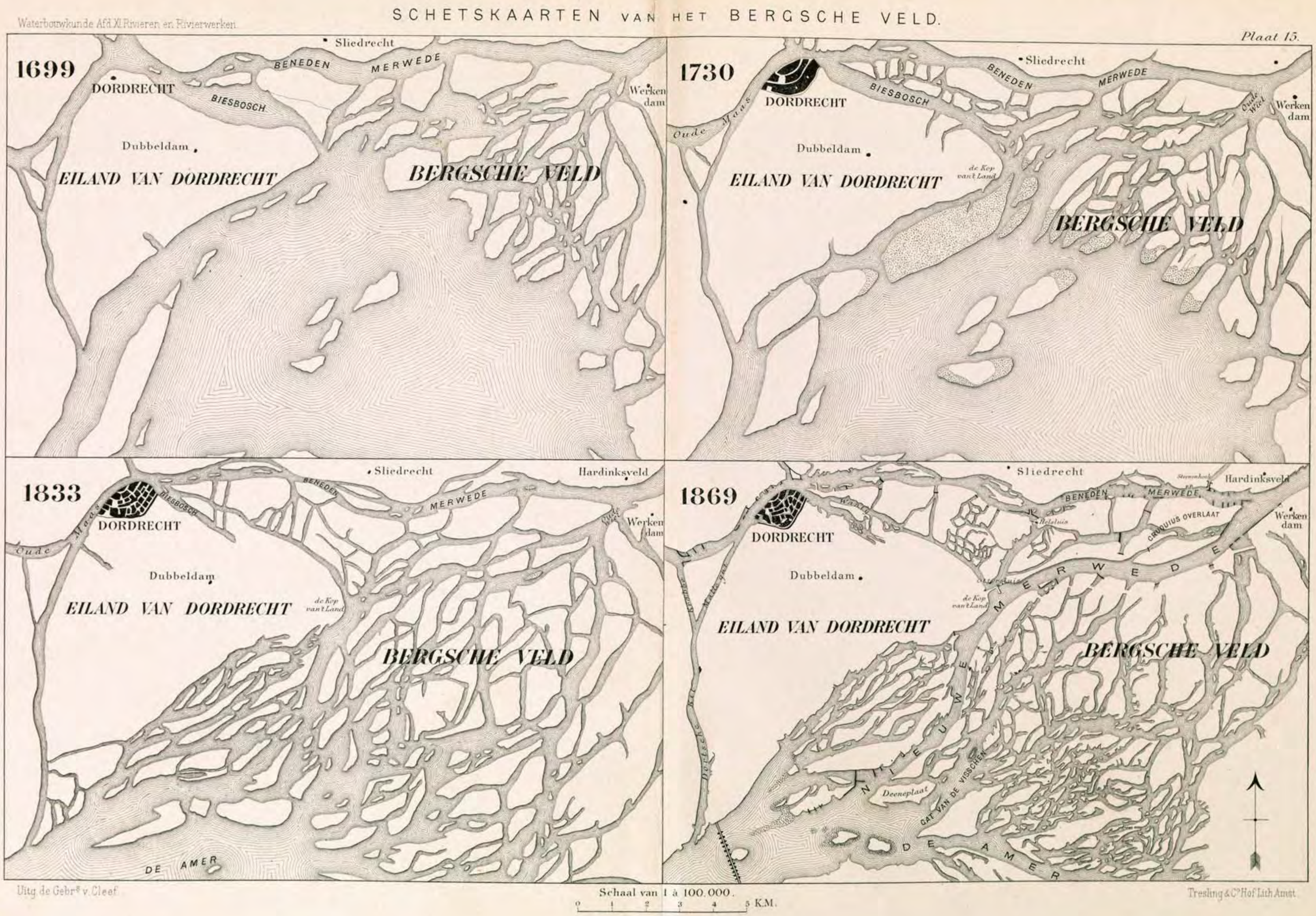

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3 Shifting of an IJssel River bend due to erosion at the outer bend and sedimentation at the inner bend **4** Old river maps for the Biesbosch area **5** Biesbosch

Period from 1600 to 1800

The IJssel had already started to silt up during the course of the 15th century. Shipping bound for the Hanseatic towns along the IJssel was severely disrupted by this phenomenon. Rivalry amongst the Hanseatic towns prevented them from taking joint action to deal with this problem. As a result, in 1629, during the Eighty Years' War, Spanish soldiers were able to cross the river on foot, and in the disastrous year of 1672, Louis XIV of France and his troops waded through the Rhine at Lobith. At the end of this war, after the Treaties of Nijmegen had been signed in 1678, the water question was put firmly on the political agenda.

During this period, the riverside areas were frequently ravaged by inundations. After the construction of the Pannerdensch Kanaal (1707), much more water passed through the Nederrijn and the IJssel, which resulted in a great many dyke bursts along these rivers. This can still be seen from the numerous pools in the area. These small round pools (known locally as wielen or waaien) are potholes that are created at the spot where a dyke bursts. The floods were caused not only by high river discharges, but also by ice dams in particular. In winter, ice floes became stranded on the shallow winding riverbeds and the water behind the ensuing ice dams backed up to such an extent that a large number of dyke bursts resulted. The continual inundations, together with international agreements on the distribution of discharge, induced the Dutch to establish a policy of centralised water management, and to this end, the Bureau voor den Waterstaat (Water Management Office) – the forerunner of Rijkswaterstaat – was established in 1798.

300th anniversary of the Pannerdensch Kanaal

In 1702, the States-General resolved to construct an entrenchment (a protective embankment with canal) near Pannerden. And in 1707, this canal was widened to form the Pannerdensch Kanaal. In 1769, a dyke bursting along the canal caused a considerable flood disaster. Part of the inundated area was part of the former Duchy of Cleves and had meanwhile become part of Prussia. This had even resulted in an international conflict. During a conference in Arnhem in 1771, the parties involved drew up a treaty on improving the bifurcation points. Amongst other things, this treaty contained an agreement to allow two-thirds of the Rhine water to flow through the Waal and one-third through the Pannerdensch Kanaal at the Pannerdensche Kop. This discharge distribution has been carefully kept up ever since, and still applies today.

The Pannerdensch Kanaal is now 300 years old, and the issues concerning water distribution at the time of its construction are still very much alive. Is the Rhine water being optimally distributed among the Waal, the Nederrijn-Lek and the IJssel? Is our national water management sufficiently flexible? And are we in a position to cope with changes in the climate, the spatial planning of the region and use of the canal?

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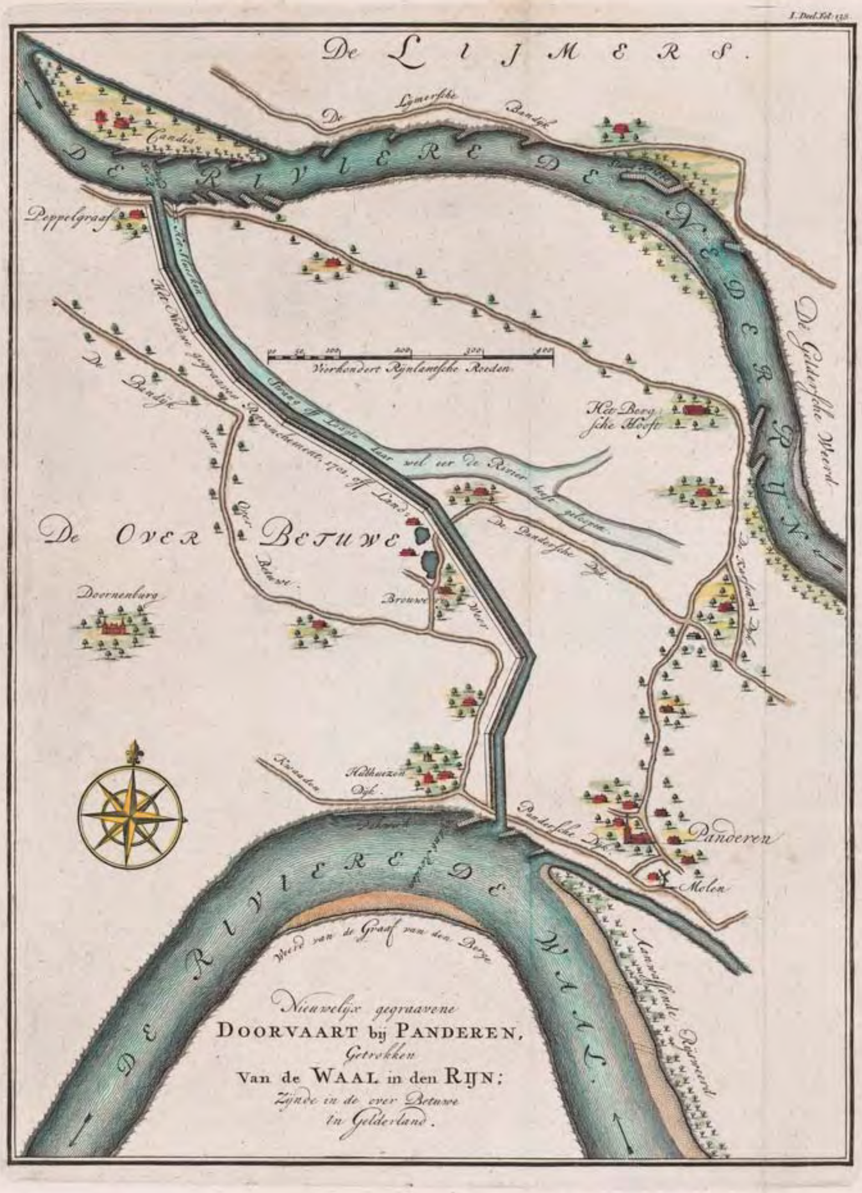

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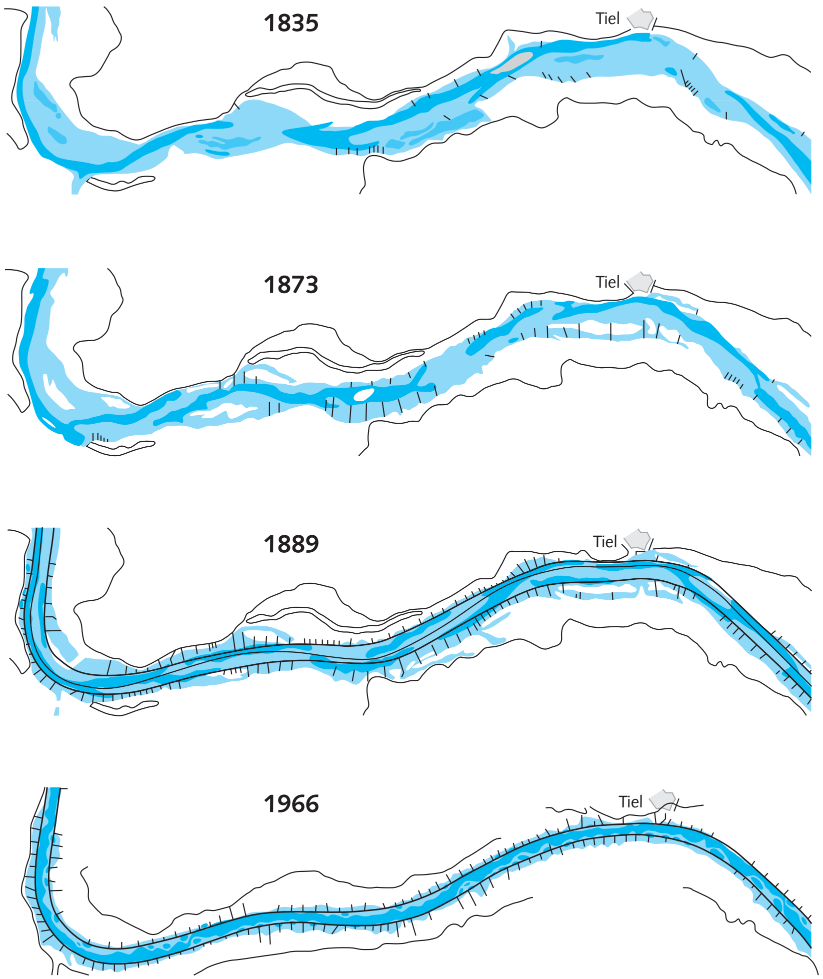

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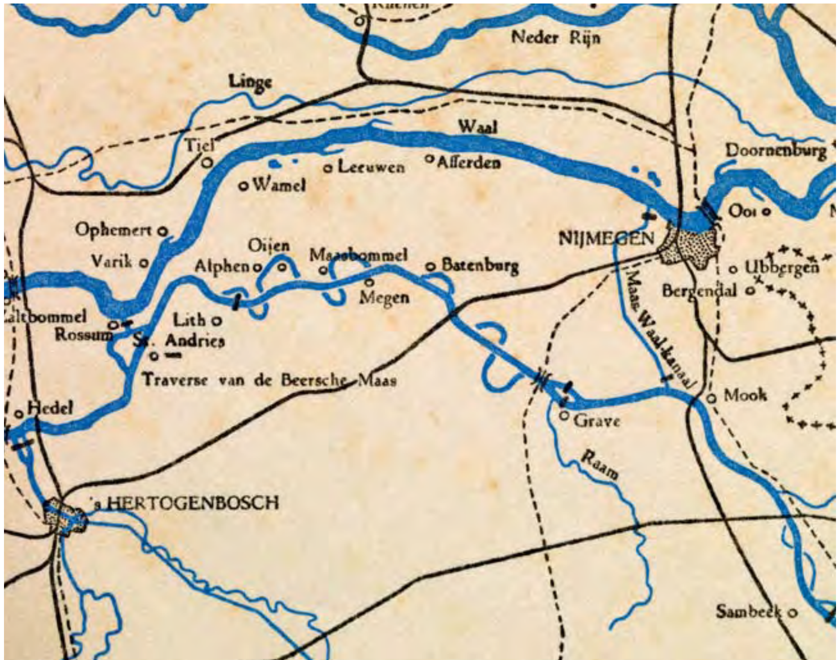

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Period from 1800 to 2000

The riverside areas have been adapted at a fast rate since 1880 in response to the numerous inundations and ice disasters in the 19th century. Main channels have been systematically fixed, straightened out and reduced in width ('trained') using groynes and dams. Although this was primarily intended to prevent ice dams from forming, shipping also derived considerable benefit from deeper and straighter waterways. Damming up old watercourses and digging new ones allowed the rivers to discharge more water and flow more rapidly to the sea, and to this end, rivers such as the Nieuwe Merwede (1874) and the Bergsche Maas (1904) were dug out. The Nieuwe Waterweg (1872) was dug out to improve the shipping route. A total of 10 weirs were constructed along the Meuse and the Nederrijn-Lek in order to regulate the distribution of water and to enable shipping to navigate the waterways.

In 1932, the Zuyder Zee was closed off from the sea by building the IJsselmeer Dam, and the IJsselmeer (a freshwater lake) was created. After the North Sea Flood in 1953, the Delta Works were constructed in the south-west of the Netherlands, and most of the estuaries have been closed off with dams ever since to offer better protection against storm tides. This has resulted in a strong decrease in tidal and salt-water influence in a large part of the Rhine-Meuse estuary.

Geomorphological processes

In natural rivers, there are so-called geomorphological processes at work, such as large or small-scale erosion and silting or sedimentation. These processes result in natural levees, new meanders, sandbanks, islands, river dunes and secondary channels. The geomorphological processes ensure that new habitats are continually being created for all kinds of plant and animal life native to riverside areas.

The course of the Rhine and Meuse is largely a fixed one, due to the construction of dykes, groynes and bank protections. Large-scale geomorphological processes no longer occur in the Netherlands, so that secondary channels and islands, for instance, are no longer formed by natural processes. Most of the geomorphological processes nowadays occur in the Waal, the IJssel, the Grensmaas and the Boven-Merwede. These are apparent in features such as sediment deposits (sand, silt, gravel) on the inner and outer bends of the rivers: water in the outer bends flows rapidly, so only the coarsest type of sediment is deposited (coarse sand and gravel), while water in the inner bends hardly flows at all, allowing finer sediment to settle. In addition, sand dunes bank up along the Waal, and it takes a great deal of time and effort to keep the inner bends at a sufficient depth to accommodate shipping. Geomorphological processes on other river courses have all but disappeared.

6 Louis XIV crossing the River Rhine at Lobith (12 juni 1672). Painting by Adam Frans van der Meulen, Rijksmuseum Amsterdam **7** Map of the newly excavated channel at "Panderen" (1701), forerunner of the Pannerdensch kanaal. These defensive works were not branched to main channel by that time. **8** Regulation of the Waal in the 18th century. The width was reduced from 500m to 260m, islands and shoals were removed and the riverbanks were fixed with groynes **9** Map from the 1930s showing cut-off bends. From JAC P. Thijse - 'Onze Groote Rivieren (1938)

With the aid of old maps of the rivers, Rijkswaterstaat has studied those aspects of rivers that coincide with the occurrence of geomorphological processes. It has transpired that the ratio between the river's width and its depth gives a significant indication in this regard. If this ratio is slight, or in other words, if the river is quite deep in relation to its width, not much sediment is deposited in general, while the greater the width-depth ratio, the more possibility there is of sandbanks and natural levees forming. This knowledge is important to rivers' ecological recovery.

Changes in the catchment basin

It is not just the courses of the rivers themselves which have undergone major transformations during the past centuries: the entire catchment basin looks quite different today than it did in the Middle Ages. Land reclamation has resulted in less fen and marshland, while there was less woodland in the Middle Ages because people in those days used much more timber and had a greater need for agricultural land. The surface area of the woodland has not changed during the past century, although there are more coniferous woods than deciduous woods nowadays.

Agricultural activity has become much more intensive since the 1950s, and built-up areas have increased considerably. The present-day extensive network of metalled roads inhibits easy absorption of precipitation directly into the ground, and efficient drainage of fields has led to superfluous water being rapidly drained off by ditches. The result of these factors is that nowadays precipitation reaches the rivers much more quickly. Although as it happens, this effect is of less significance during flooding, since in that case the soil is already saturated by rainfall and even an unmetalled surface would not have been able to absorb any more water.

It is difficult to say precisely what effects the changes in land use, taken separately, have had on river discharge. This is because a number of the effects overlap and because natural drainage fluctuates a great deal.

RIVER RECOVERY

Most of the rivers' original, dynamic nature has been lost due to all the changes during the past centuries. As a result, the riverside area has become much less attractive for plants and animals native to such areas. Species that live on sand and gravel banks, in banks with steep eroded walls, or in shallow running water are barely able to find a suitable habitat in present-day Dutch riverside areas. Species native to swamp and reedlands have also lost a lot of their natural habitat due to the cultivation of floodplains and basins. Many of the typical salt marshes and mud flats along the lower courses of the Rhine and the Meuse, along with their corresponding tidal plant and animal life, have disappeared as a result of the estuaries being dammed up. The IJsselmeer Dam and the Haringvliet Dam are a hindrance to fish and other organisms that live on the boundary between fresh and salt water. Although migratory fish such as salmon, sea trout, lampreys and shad grow to maturity in the sea, they have to swim up-river again to find suitable spawning grounds. But nowadays, these fish have

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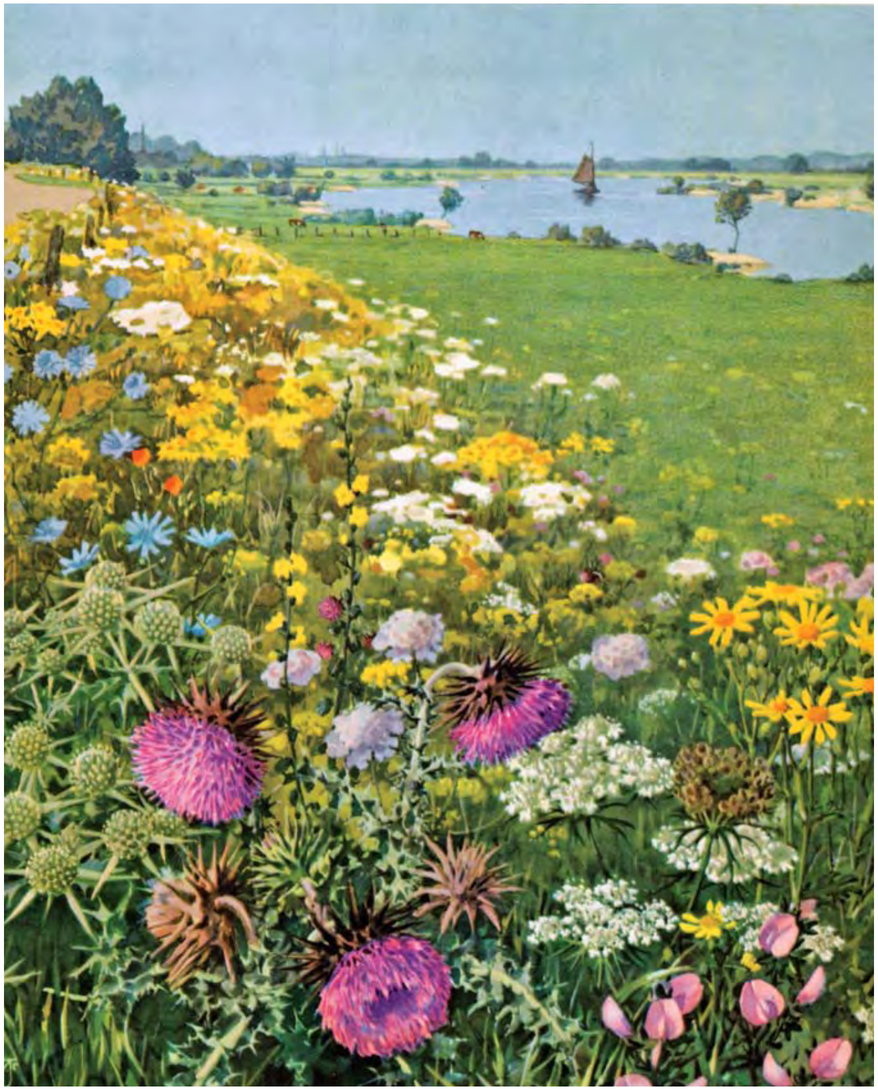

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to negotiate dozens of weirs in the Netherlands, as well as in the countries situated upstream, on their way to these spawning grounds.

Countries situated on the Rhine and the Meuse have been working on the recovery of these rivers since the 1980s. Floodplains are being restored in a more natural manner, often in combination with improved flood-protection. The discharge sluices along the IJsselmeer Dam are now being managed in such a way as to enable migratory fish to pass more easily, and by the same token, the Haringvliet sluices will also stand ajar at floods in the near future. This in turn will once more lead to a gradual transition from fresh to salt water in the Haringvliet. Almost all of the weirs in the Rhine and Meuse rivers have been fitted with fish ladders.

By adopting the Birds and Habitats Directive and the Water Framework Directive, the European Union has given a considerable impetus to the conservation of existing natural environments and to restoring those that have been destroyed. The countries in the catchment areas will have to join forces to ensure improvement of water quality and ecological values, even in rivers like the Rhine and the Meuse that have been designated as heavily-modified rivers.

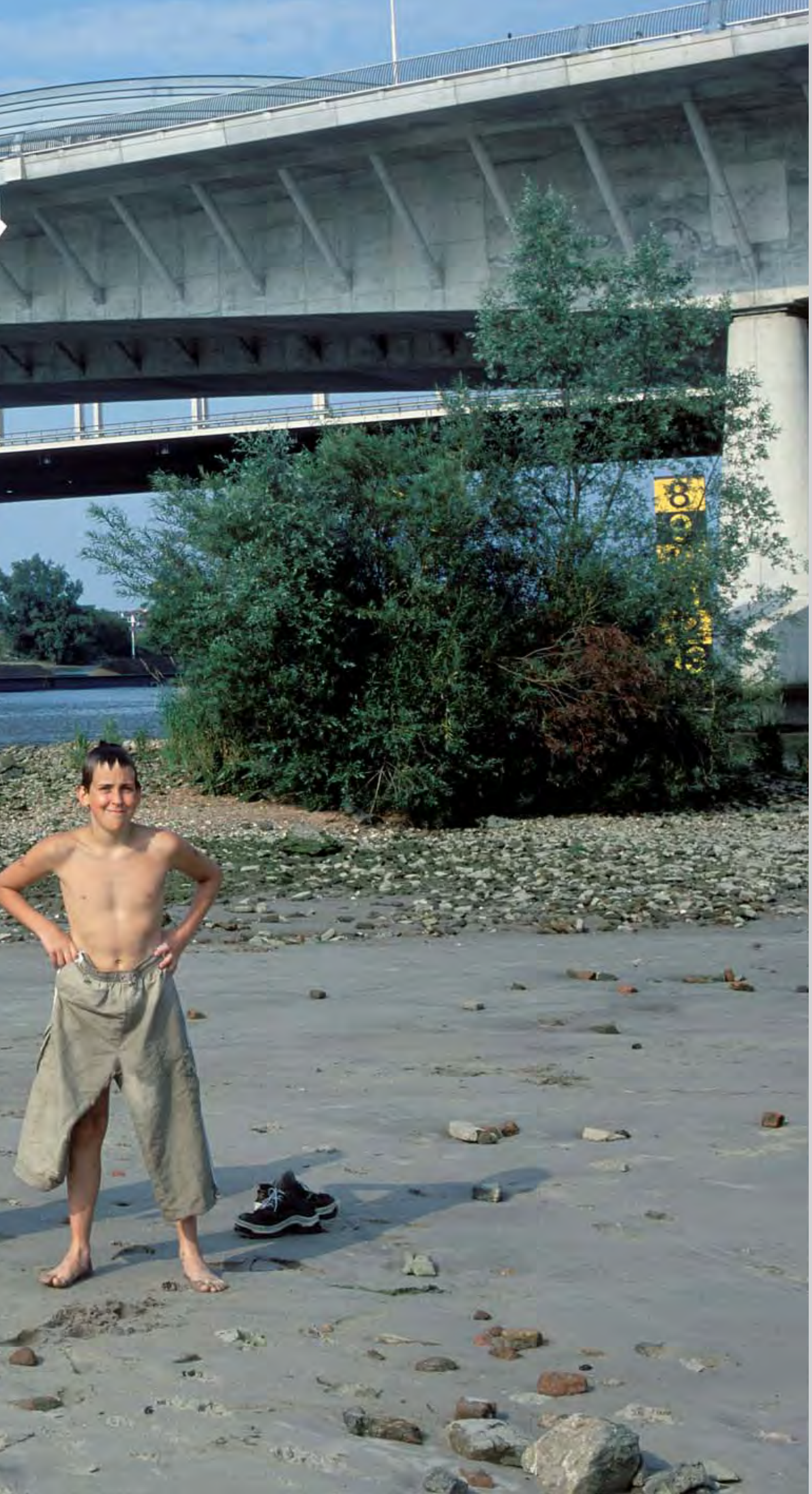
Our major rivers

"Not so very long ago – possibly 15 years or so – I made so bold as to say that the countryside bordering our major rivers, hemmed in between the dykes, or in other words, all the land covered by the main beds, could be regarded as open and natural country. The winter tides would doubtless keep human intervention within reasonable bounds. I naturally made a reservation with regard to such activities as arable farming, stone quarrying, or road construction.

These days, I am not so ready to make such an allegation, particularly after all the human activity I have seen along the banks of the River Meuse. And who knows what awaits us along the Geldersche IJssel. Notwithstanding all this, the wide world of floodplains (either meadowland or woodland), the dead river arms or creeks – large and small – the pools and the potholes, and finally, the groynes and the dykes still provide us with fascinating scenery, not only by virtue of its great natural picturesqueness, but also thanks to its rich diversity of plant and animal life."

Source: Onze groote rivieren (Our major rivers) by Dr Jac. P. Thijsse (1938).

10 The Maas at Lienden **11** Fishway at Grave **12** Watercolour by J. Voerman jr. - 'Dijkhelling met bloemen' taken from JAC P. Thijse - 'Onze Groote Rivieren' (1938)



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RIVERS IN EVERYDAY LIFE

Rivers transport water, ice and sediment to the sea. In addition, people throughout the ages have used rivers for all kinds of purposes, such as shipping, discharging waste water, recreation, extracting minerals, producing drinking water, and irrigation. More and more space in the vicinity of the rivers is being appropriated for the construction of homes and industrial estates. Legislation and regulations restrict the use of this space in order to ensure that all practical functions get a chance and that the river can continue to discharge its water safely.

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Numerous activities are carried out in and around rivers. For shipping, rivers are important transport routes between the ports on the coast and the hinterland, as well as domestic and international destinations. Rivers are also important waterways for recreational navigation. River water is used for sprinkling and to prepare drinking water, industrial water and cooling water. In summer, river water is drained off to keep the water level sufficiently high in lakes, ditches and canals. In the northern and western Netherlands, river water is also used to flush polder water with fresh water and to counteract the influence of salt sea water. Hydroelectric power stations in the rivers generate electricity, while the floodplains provide space for agriculture, as well as for nature development and recreation to an increasing extent: for inhabitants of the major cities, riverside areas are places where they can get away for a day's recreation. Sand and gravel are dredged from the riverbeds, while clay for the brick industry is extracted in the floodplains: this is sometimes done in combination with nature development or dyke improvement. Waste water and waste products are transported along with the water, although most waste water nowadays is first purified before being drained into the river.

Safety as a precondition

Besides all these different uses, the river must maintain enough space to be able to accommodate extremely large amounts of water in exceptional cases. Moreover, dykes, weirs, barriers and other construction works must remain sufficiently stable and continue to function properly. For this reason, each activity carried out which affects the riverbed requires a permit from Rijkswaterstaat. The official charged with granting the permit evaluates whether the activity is acceptable, and sets appropriate conditions if necessary.

The rivers have lost a great deal of space during the course of time. In spatial planning, a satisfactory balance must be found between guaranteeing public safety and the large

1 Recreation **2** Sand and gravel extraction **3** Drinking water **4** Shipping **5** Agriculture **6** Flood protection **7** Nature **8** Generating power **9** Cooling-water **10** Hartelkering at Spijkenisse **11** Oosterscheldekering **12** Maeslantkering on the Nieuwe Waterweg demand for space for other functions. A policy line was drawn up in 1997, which considerably restricted new construction activities in the riverbed. Although this was generally effective, it turned out to be impossible to start up certain necessary spatial development projects, and land neglect appeared imminent.

To resolve this problem, a new Policy Line for Major Rivers was established in 2006. This has enabled the authorities to allocate a new purpose to existing development in the riverbed in order to prevent lack of occupancy. In addition, the new policy line provides more options for use in places where there is (practically) no flow at flood discharge (storage area). If water storage is lost as a result, this will have to be compensated at another location in the riverbed. Stringent restrictions will still apply at places where the water has to be able to flow through.
Fifteen locations in the riverside area have been designated as places where municipalities are allowed to experiment with new types of construction such as floating homes or houses on piles. Supplementary layout measures have been introduced to ensure that the river is given more space on balance at these locations.

Nature

Nature is gradually winning more terrain along the rivers. Webs of nature areas are being created, both on a national and an international scale: the National Ecological Network in the Netherlands and Natura 2000 in the European Union. New nature areas frequently replace agricultural land. The idea behind this new nature is to restore natural habitats for species that originally dwelt in the riverside areas. The development of new nature is often a secondary objective when creating more space for water: for example, constructing subsidiary channels in floodplains results in shallow running water for fish, as well as increasing the flow capacity during flood discharge.

Agriculture and fisheries

About three-quarters of the floodplains and riparian zones are used for agricultural purposes. These farm lands comprise pastures for cattle, arable farming land, glasshouses, rose and tree nurseries, and orchards. Agriculture not only takes up space, but also makes demands on water management: sufficient fresh irrigation water must be present in the river, particularly in times of drought. The salt content requires special attention – especially in the Rhine-Meuse estuary – if river discharge is low and the salt water is able to penetrate further inland.

Only a few commercial companies still fish the rivers. Many species of fish caught in the past (such as salmon and allis shad) have become extinct, or no longer live there in sufficient numbers to be commercially interesting. One of the reasons for this is that many fish-spawning grounds have been destroyed due to land reclamation or have become inaccessible as a result of weirs and dykes. Nevertheless, the river water is now so clean that river fish is once more suitable for human consumption. This has aroused increasing interest on the part of commercial fisheries.

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Recreation

River dykes are attractive routes for cyclists, and walking along the river banks is a popular pastime. Some floodplain managers lay out special 'browse routes' for walkers, while ferries provide visitors with a means of continuing their route on the other side of the river. Sand and gravel lakes are eminently suitable for different types of recreation, such as surfing and swimming. Recreation centres have frequently been set up here, like those in the Maasplassen region near Roermond and Rhederlaag near Arnhem. Swimming in the main river channel is strongly discouraged because the currents there can be treacherous.

And the river itself is put to full use for recreational boating. An estimated 200,000 pleasure boats for touring are in use in the Netherlands, particularly cabin cruisers. The Meuse, the IJssel and the Nederrijn-Lek form a part of the basic national boat tour network, which comprises a total of approximately 4,400 kilometres. In order to avoid creating dangerous situations with professional shipping, the government is seeking alternatives for the recreational routes along these major navigation waterways. Due to the considerable numbers of professional vessels, the Waal is not incorporated in the basic boat tour network. The Grensmaas and the Biesbosch are popular for canoeing.

Drinking water

In most of the Netherlands, drinking water is prepared from sub-soil water. The sub-soil water in the western part of the Netherlands, however, is not suitable for this purpose because of its high salt content, so water from Rhine and Meuse is primarily used in this region. The purification process is more expensive because this surface water is more polluted than sub-soil water.

Up till the 1960s, drinking water for the south-western Netherlands was prepared from Rhine water, but as pollution increased, the authorities decided to change over to water from the Meuse. However, this rain-fed river transports very little water in dry summers, although this is the time of year that the demand for drinking water is the greatest. For this reason, three storage reservoirs in the Brabant Biesbosch were put into operation in 1973; these provide sufficient buffer stock to supply the Randstad with water for three months. Storage reservoirs have also been constructed in the Sliedrecht Biesbosch and along the Oude Meuse.

Bank infiltration is carried out at a number of locations along the major rivers, in which sub-soil water – most of which comes from the river – is extracted in the immediate vicinity of the river. This river water is filtered through the soil and subsequently purified. This produces cleaner water than purifying the surface water, and causes less excessive drainage than ordinary sub-soil water catchment. Use of the bank infiltration method will therefore increase during the coming years.

13 Skaters on the frozen floodplains of the Waal

Cooling water and hydro-electric power

There are nine conventional power stations situated on the major rivers which use the river water as cooling water. Four of these power stations are situated at the Hagestein, Amerongen, Linne en Lith weirs in the Meuse and the Nederrijn-Lek, where energy is generated from the fall of the water. There are also plans afoot to construct hydro-electric power stations for other weirs along the Meuse. However, this green energy does have one drawback: fish migrating downstream risk ending up in the turbines, and most of them would not survive this: long fish such as eel are particularly vulnerable. Research is currently being conducted to see whether this can be avoided by e.g. fish guiding systems that can conduct the fish along a safe route.

Power station	**River branch**	**Capacity (MW)**
Traditional power station		
Harculo	IJssel	353
Nijmegen	Waal	602
Galileïstraat	Nieuwe Maas	209
RoCa	Hollandsche IJssel	270
Amer	Amer	1390
Moerdijk	Hollandsch Diep	340
Claus	Meuse	1280
Willem Alexander	Meuse	353
Maasvlakte	Maasvlakte	1040
Hydro-electric power station		
Hagestein	Lek	1.8
Amerongen	Nederrijn	10
Linne	Meuse	11.5
Lith	Meuse	14

Traditional and hydro-electric power stations along the major rivers

Mineral extraction

Raw materials for building have been extracted in the riverside areas since the time of the Romans, and the brick and roof tile industry showed considerable growth during the 19th and 20th centuries in particular. The brick factories dating from this time now form striking elements in the surrounding landscape. During the second half of the 20th century, more stringent requirements were laid down for the extraction of clay, sand and gravel in order to prevent large holes from forming throughout the entire riverside area. The possibilities of combining mineral extraction

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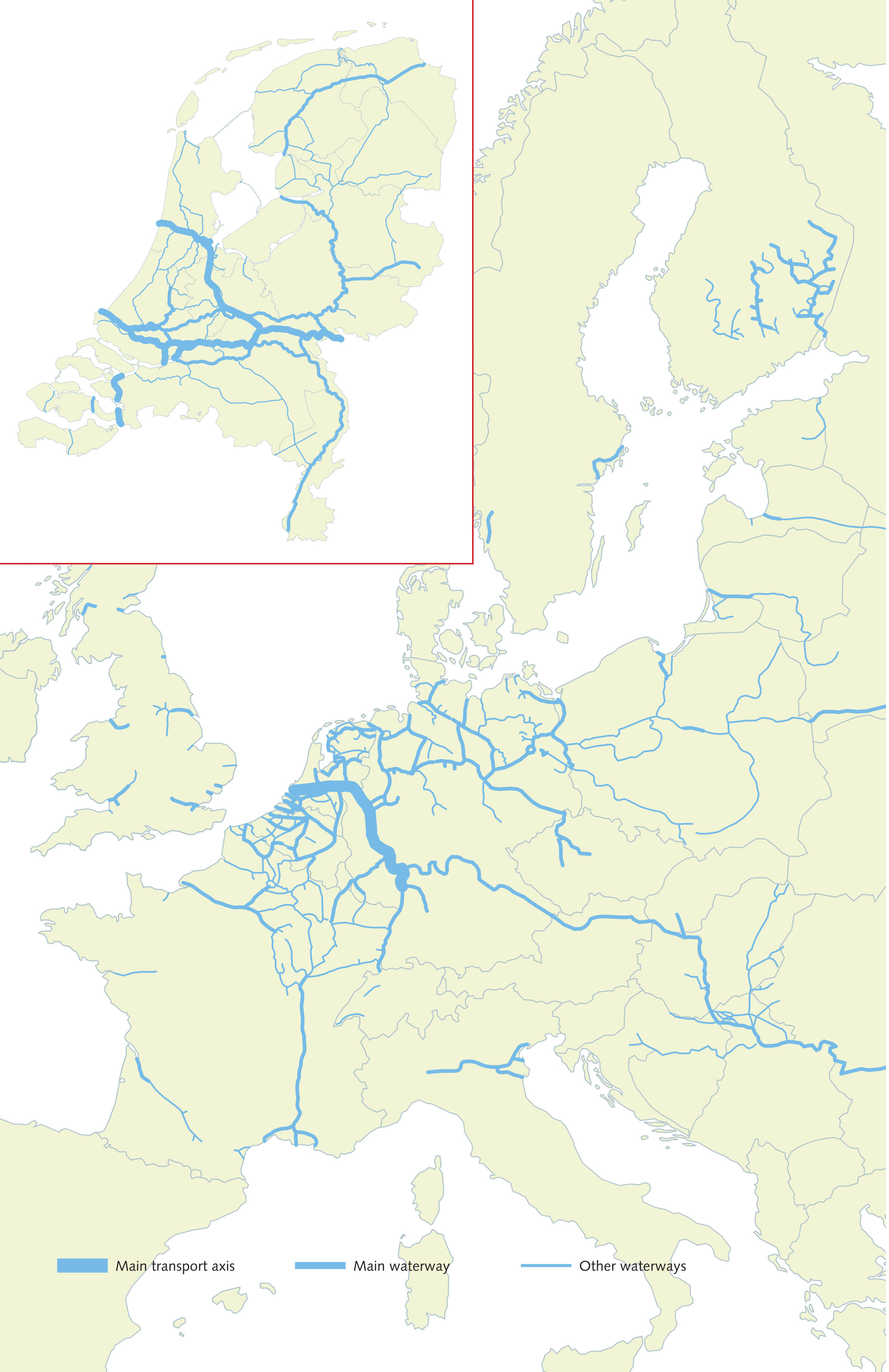
with room for rivers and nature development are currently being investigated.

Generally speaking, the layers of clay in floodplains are no thicker than 1 to 2 metres.. This is why clay extraction does not usually leave any deep scars behind, and provides plenty of opportunities afterwards for all kinds of uses. Sand for filling-up and industrial purposes is also extracted in the riverside area, especially around the Merwede and Lek. Extraction of sand in the main channel is combined with dredging for the shipping industry, while gravel is extracted along the Meuse. The large, deep lakes in the Maasplassen region are the result of previous gravel extraction, although nowadays, increasing preference is given to superficial gravel extraction. During the next few years, gravel extraction in the Grensmaas will be combined with river enlargement and nature development.

SHIPPING

The Dutch delta is the natural port of access for shipping bound for a large part of Europe. The Port of Rotterdam is favourably situated at the Rhine-Meuse estuaries; this port constitutes a natural link between economic centres in Europe and the other continents. Thanks to this situation, Rotterdam has developed into Europe's major import centre, and the Port of Rotterdam's economic importance will increase still further as a result of the enlargement of Maasvlakte 2 (www.maasvlakte2.com). Major port and industrial areas have also been constructed near Moerdijk and Dordrecht. The Waal links the Port of Rotterdam up with the German hinterland and is the busiest river in western Europe, although the Nederrijn-Lek, the IJssel, the Meuse and the waters of the Rhine-Meuse estuary are also important transport arteries. The Netherlands also has a finely-divided network of smaller waterways, enabling many destinations to be reached by inland navigation vessels.



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14 Seagoing vessel in the IJmuiden sluice **15** Weir in the Maas at Belfeld **16** Level of shipping intensity on the European waterways. *Source: The AVV Transport Research Centre (Ministry of Transport, Public Works and Water Management)*

On 17 October 1868, France, Switzerland, the German States, Belgium and the Netherlands signed the Act of Mannheim. This was an agreement between these countries to ensure clear transit for Rhine shipping right up to the open sea and to guarantee equal treatment for all shipping.

Waterways

The network of waterways in the Netherlands consists of major transport axes, main waterways and other waterways. The major transport axes and main waterways comprise a total of 2,200 kilometres in length. A major transport axis is a waterway navigated by more than 5 million tons of cross-border goods transport per annum to and from Dutch seaports. Four-barge tugs can sail along the major transport axes, although certain major transport axes (Nieuwe Waterweg, Merwede, Waal and Upper Rhine) can even accommodate six-barge tugs. An average of 165,000 ships pass along the Waal annually, which transport a grand total of 160 million tons of goods. The Meuse, Nederrijn-Lek and IJssel are main waterways in the riverside area; the minimum volume of transport conveyed along a main waterway is 5 million tons per annum, or 10,000 containers. Larger motorised vessels with a cargo capacity of more than 1,500 tons and two-barge tugs can also navigate these main waterways. Shipping traffic on the Meuse has increased considerably since the canalisation of the Meuse and the construction of the Meuse-Waal canal: in 1930, 15,000 ships passed through the navigation lock near Sambeek, while in 1996, this number had increased to 55,700 ships, with a cargo capacity of more than 41 million tons. The other waterways are primarily of local and regional importance.

Ships on the Nederrijn-Lek and the Meuse have to go through a number of locks and weirs, which ensure that the depth of the water remains sufficient. In the Netherlands, the Waal is navigable under almost all circumstances, although ships with a full cargo are sometimes unable to sail along the river at low water. Shipping is prohibited in the case of extremely high water levels in order to prevent suction and wave action from damaging banks and houses.

Economic significance

A large part of goods transports to and from the Netherlands is carried out by sea, coastal shipping and inland shipping. Seventy-five per cent of Dutch exports and 35% of imports are transported by sea, while inland shipping transports 35% of domestic and hinterland cargo (in tons). This percentage is much less in other European countries (about 7%), which means that the Dutch inland navigation fleet is the biggest in Europe, with a flag share of about 50%. Inland navigation has shown a steady growth over the past years; although the number of vessels is decreasing, cargo capacity is on the increase. Since Dutch waterways offer opportunities for further growth, inland navigation can contribute to resolving international transport problems. Water transport is cheaper per kilometre and per ton of goods than other means of transport, and it is also a great deal cleaner.

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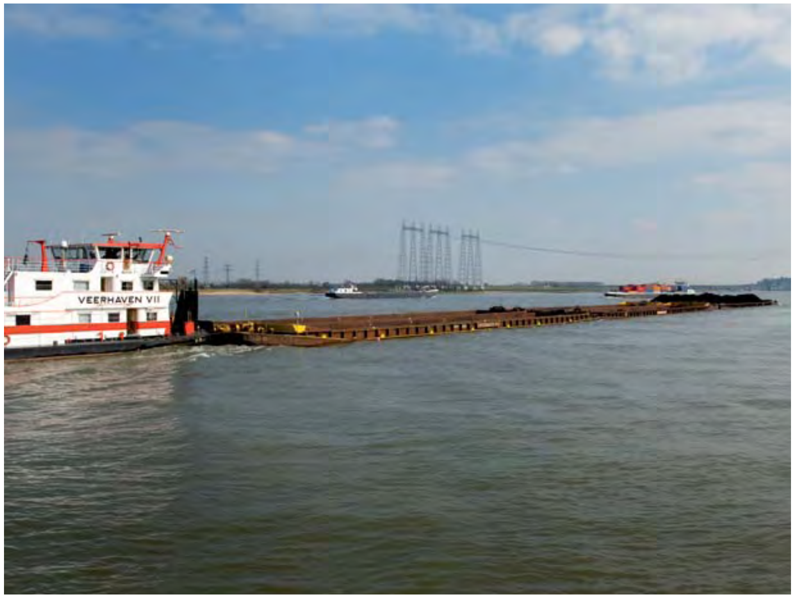

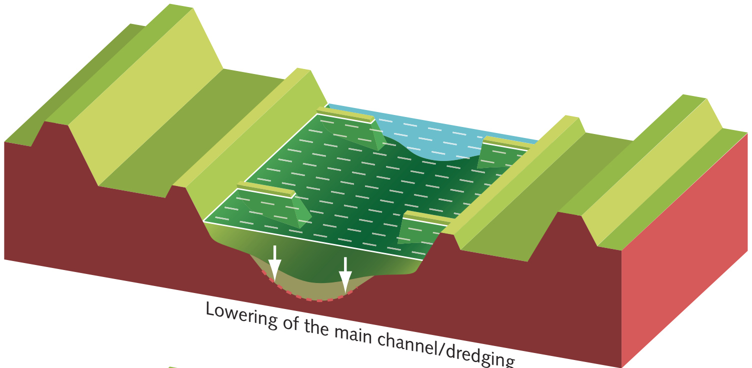

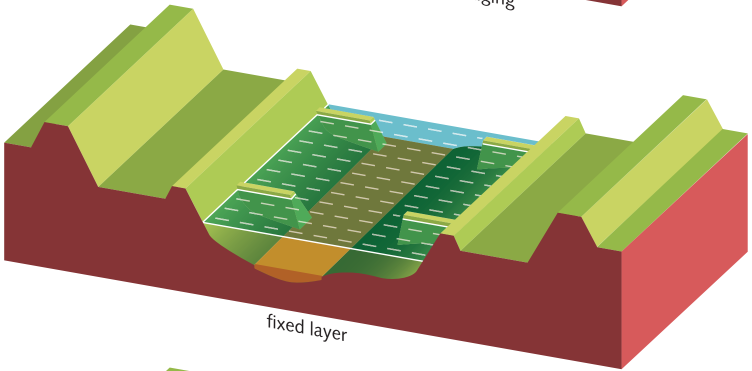

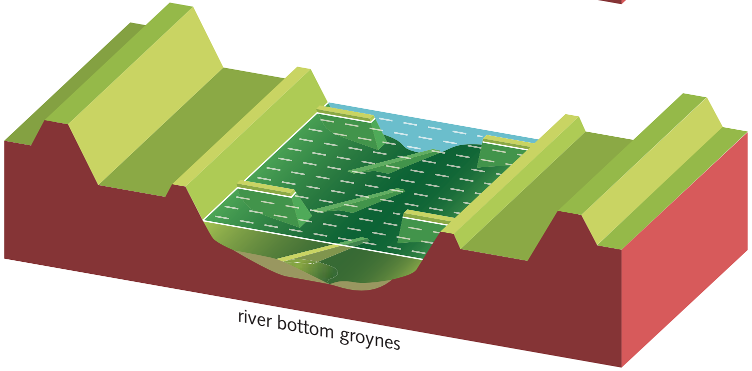

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Six-barge tugs

Inland navigation vessels come in all shapes and sizes, ranging from the small 300-ton spits to six-barge tugs with a cargo capacity of 17,000 tons. A six-barge tug can use this capacity to transport the same volume of goods as 640 lorries forming a queue of about 7 kilometres. There are different types of six-barge tugs: in its long form, a six-barge tug is almost 300 metres long and about 35 metres wide in its broad form.

Percentage of transported goods in tonnes in the Netherlands, 2005. *Source: AVV*

Seagoing shipping	20%
Inland shipping	21%
Road transport	47%
Railway transport	2%
Pipelines	10%

Waterway improvement

Safe, smooth and cost-effective shipping requires a wide, deep channel. Ships should preferably be able to pass one another safely under all kinds of conditions: at high and low water, in rain and fog, and also if there are sandbanks or strong currents in the river.

Ships navigating the Meuse can draw up to a maximum depth of three metres, which means that a great deal of cargo capacity is unused. Rijkswaterstaat is implementing the Meuse Route Project, which will increase the channel depth by half a metre so that ships can carry more cargo. This means that the length of the ships can also be increased from 110 to 190 metres. Thanks to these alterations, shipping on the Meuse will be in a better position to compete with lorry traffic on the roads. The European Commission actively supports the improvement of the Meuse route because the Meuse is one of Europe's important major waterways: many big companies in Belgium, France and the Netherlands are accessible via the Meuse.

Between 400 and 500 ships navigate the Waal's 'water motorway' every day. In order to ensure that this busy traffic is able to proceed smoothly, the Waal Project has been started up to enlarge the waterway, construct overnight harbours and improve traffic surveillance. Enlargement of the waterway consists of widening and deepening the waterway between Lobith and Gorinchem. If the river is 30 centimetres deeper, ships can transport as much as 10% more cargo. Rijkswaterstaat is investigating whether this would be possible by means of dredging and constructing bend-way weirs and permanent layers, which will dispose of the shallows. If sufficient overnight harbours

17 Container ship at the Calandkanaal **18** River measures for improving the waterway are constructed, ships will not have to anchor in the waterway itself by night or if the weather is bad. This is why new overnight harbours are being constructed at Lobith and Weurt, while the existing harbour at Haaften is being expanded. The number of radar stations has been increased to improve traffic surveillance: these stations are operated from the new traffic station at Nijmegen.

New bottlenecks are anticipated for the future in the Waal: the bottom of the Waal and the German Rhine is subsiding. Bars in the waterway are created at places with hard soil strata, and since the water level is sinking along with the bottom, these bars form a hindrance to shipping. Rijkswaterstaat is examining the possibilities of preventing this problem from arising and stabilising the subsidence. Low water levels may occur more frequently in the future due to climate change, and Rijkswaterstaat is currently investigating possible solutions to this even now, such as constriction of the minor riverbed if the water level is low, or a different water distribution.

"My wife and I sailed on the Rhine together for four years, and when the children came along, we had to choose between sending them to boarding school and finding another job on the water. We finally chose the latter option: in 1970, when I was 25, I started work as lock boy at the Driel lock. And this summer, in 2007, I'll be retiring as Chief Lock Operator. I've been working here for almost 40 years, and I've seen a lot of changes during this time.

For instance, last year we asked the people who use the lock if there were any improvements they'd like to suggest. This was the first time we'd ever done this and the reason was that the lock was going to be renovated. We wanted to let the users know about it in plenty of time. Rijkswaterstaat thought that this would be a good way of asking the skippers what they thought of the lock: whether we were providing the right kind of service, and if there was anything we could improve.

We asked professional masters and captains of pleasure boats this question on two separate evenings. It turned out that the captains of pleasure boats were annoyed by the fact that professional masters often keep their propellers going in the lock chamber, which is against the regulations. And this means that the more lightweight recreation yachts are difficult to control. They also said they'd like the lockmaster's instructions on entering and leaving the lock to be clearer. Professional masters in turn are annoyed with captains of pleasure boats who don't moor their boats properly and get in the way.

In the summer, we joined forces with the other locks to launch a campaign called 'Locking through safely together'. We now use the mariphone to ask all professional masters coming up to the lock if they'd mind turning off their propellers in the lock chamber. And we also try and make sure that the pleasure boats are moored properly. The main point is that these two groups respect one another."

Kees van den Berg, Chief Lock Operator at Driel, Amerongen and Hagestein

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Traffic surveillance

With regard to safety and the Dutch economy, it is of importance that shipping traffic on the Rhine tributaries and the Meuse runs in a smooth and orderly manner. There are traffic stations situated at strategic points – including Dordrecht, Tiel and Nijmegen – along the waterway, where Rijkswaterstaat guides shipping with the aid of radar and cameras. In addition, the Rotterdam Municipal Port Management (RMPM) maintains a number of traffic stations in and around the Port of Rotterdam. The traffic control centre near Dordrecht has grown into a regional centre for everything to do with shipping on the major rivers in Zuid-Holland. Rijkswaterstaat deploys patrol boats at locations where there are no traffic stations.

New communications and information technology enable an increasingly faster and better exchange of messages to be made between shipping vessels and traffic stations. During the coming years, inland navigation will be making more and more frequent use of transmitting stations (transponders), which continually exchange information on position and cargo with the traffic control centres. The European River Information Services project will eventually result in a system whereby waterway users, traffic control centres and other interested parties are able to exchange electronic information on the position of the vessel, its cargo, its place of origin, and its estimated time of arrival (ETA).

Shipping reports

Rijkswaterstaat issues the daily news bulletins to shipping. These shipping reports provide information on water levels, obstructions on Dutch and other western European waterways, alterations in buoying and regulations, operation times for locks and bridges, and all other information which might be of importance to inland shipping. Every working day, the ‘Bulletins for Shipping’ (in writing) are sent to waterway users, waterway managers and other interested parties, and can also be perused on Teletext and the Internet (www.infocentrum-binnenwateren.nl). Very urgent messages are broadcast on the radio after the news bulletins.

For its bulletins, Rijkswaterstaat uses sources such as data from the Royal Netherlands Meteorological Institute (KNMI) and the water levels at about 70 domestic and international weather stations. The Water Monitoring System (MSW) is used for measurements in the Netherlands. This system automatically measures water levels and even discharges in some cases.

19 Traffic control at Nijmegen **20** The Ministry of Transport, Public Works and Water Management also provides markings for the waterways **21** Reconnaissance vessel from the Ministry of Transport, Public Works and Water Management in action.

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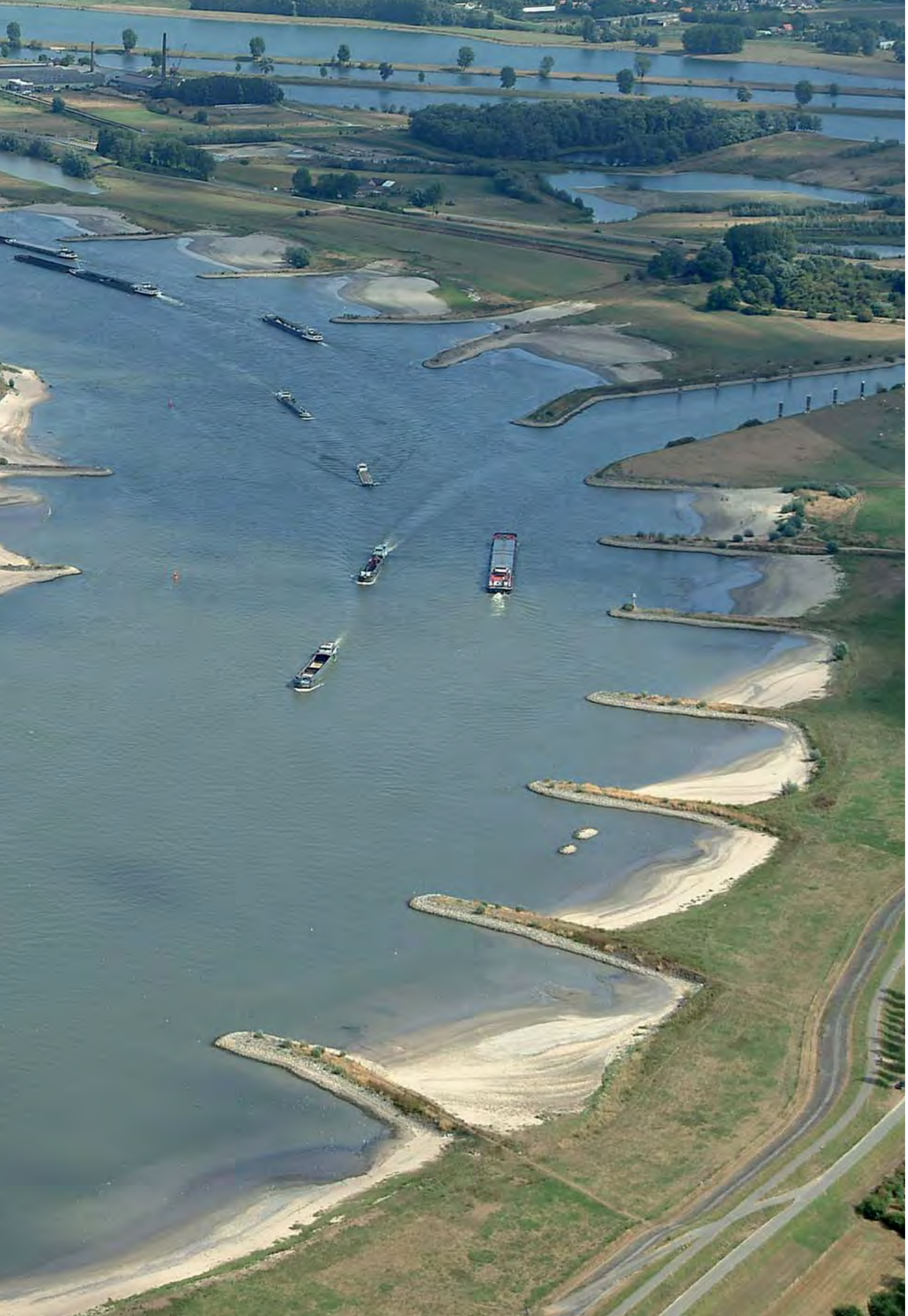
RIVERS OF SILT, SAND AND GRAVEL

Not only water flows down rivers, but also silt, sand and gravel. The faster the water flows, the more sediment is stirred up. Although the riverbed landscape is largely invisible, it is exceedingly varied, with silt plains and sand dunes up to several metres high alternating along the riverbed. The bottom of the river looks different after each high tide. And this affects shipping, water levels and the environment.

RWS is responsible for the safe discharge of water, ice and also sediment: this is laid down by law. Sediment is a collective term for gravel, sand and silt. Safe transport of sediment does not just happen by itself; river-basin managers are continually 'balancing' the sediment. These river-basin managers draw up the balance for each river course: how much sediment will be added on from upstream and how much will flow out again downstream? How much sediment will be removed from the river by dredging and how much will be added to it by sand deposits? River-basin managers also keep an eye on the places where the riverbed becomes deeper through erosion, and where it becomes higher through sedimentation.

Erosion and sedimentation

The type of sediment deposited at the bottom of a river indicates how fast the water is flowing. Silt consists of tiny platelets that hardly weigh anything. If there is a strong current, these particles float in the water, but if the current slows down, the particles stick together to form flakes.
And if there is hardly any current at all, the flakes become large and heavy enough to sink to the bottom of the river. However, even a small eddy in the water is sufficient to stir up the silt so that it floats again. This means that the current is extremely weak at places where silt has accumulated on the riverbed. Silt can be found in places like wide floodplains, behind weirs and at the bottom of deep sand-dredging pools and harbours along the river.
Gravel and sand roll along the bottom of the river as separate grains. This occurs only if the water is flowing fast enough to be able to drag them along, and the bigger the grains, the stronger the current must be to do this. The biggest grains stay where they are as soon as the current diminishes, so the current is therefore extremely strong at places where large pebbles and stones are found. In the Netherlands, this only occurs in the Meuse in the province of Limburg.



SEDIMENT AND WATERWAYS

Shipping has left its mark on the riverine landscape. It is impossible to imagine this landscape without its ships, or without the groynes, beacons, weirs and locks. Groynes ensure that the navigation channel in the middle of the river stays put and does not continually keep changing place. Weirs keep the water level artificially high so that ships do not touch bottom; ships pass through the weirs by means of navigation locks.

Shipping also influences the underwater landscape, since permanent maintenance is required to keep the navigation channel deep and stable, and riverbeds are always dynamic in spite of groynes and weirs. The water churns up sand and gravel in the outer bends and allows this to settle in the inner bends, and at high tide, the river also flows through the floodplains. The current in the navigation channel slows down at places where water flows out of the channel into the floodplains, and sand and gravel can settle at these spots. Conversely, the river flows faster where water from the floodplains rejoins the navigation channel and washes sand and gravel away. In this way, deep places and shallows are constantly being created in the rivers, and obstacles, too, can cause shallows and deeps. The shallows are a hindrance to shipping, which is why regular dredging is essential. The rates of flow in the Haringvliet and the Hollandsch Diep decreased considerably after the construction of the Delta Works, and a great deal of silt has been deposited since then. The navigation channel in the Hollandsch Diep has to be dredged regularly to keep the harbour at Moerdijk accessible.

But there are also disadvantages to dredging: it costs money, and the dredgers get in the way of shipping. In addition, the silt that settles in the lower course is often polluted, and has to be transported to expensive dumping sites. Sand and gravel are cleaner: these sediments were often sold in the past as raw materials for building. This caused so much material to disappear from the Rhine tributaries that the

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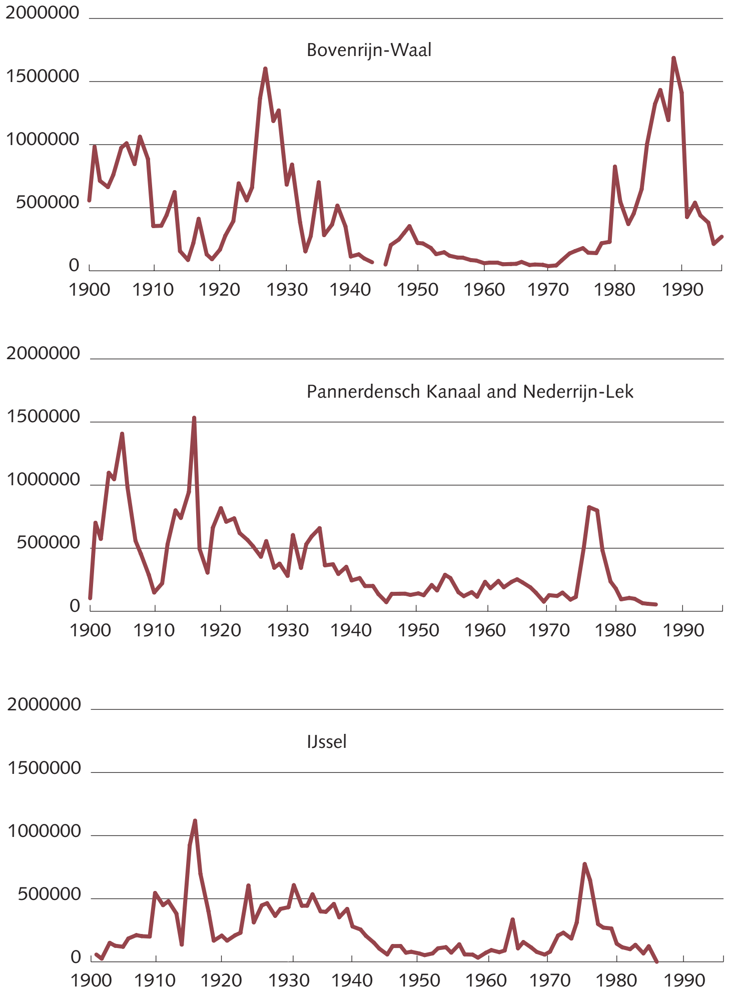
1 Groynes in a river bend in the Waal near St. Andries keep the main channel at sufficient depth riverbed has greatly subsided, and nowadays, sediment dredged up from the Waal and the Meuse has to be replaced in the river deeps.

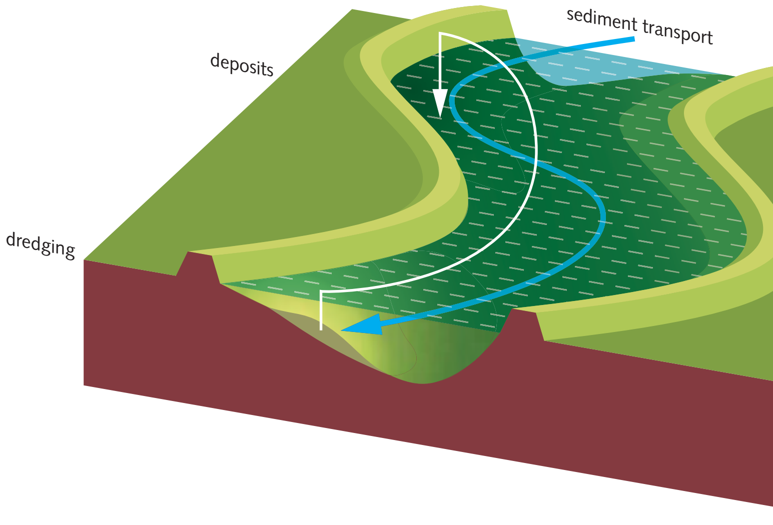
River-basin managers want to maintain the navigation channel with as little dredging as possible, and to this end, knowledge of sediment flows and of erosion and sedimentation processes is essential. When carrying out maintenance work, river-basin managers also have to take other functions into account and these sometimes have conflicting interests. For instance, river-basin managers would like to restore natural processes along the river banks so that the flora and fauna native to this habitat can return. Removing the artificial rock embankment means that erosion and sedimentation processes can start up again, and suitable habitats can develop. However, it also means that the backwash caused by shipping has more effect on the sediment, which in turn gives rise to extra silting-up of the navigation channel. River-basin managers have to be able to combine all these different interests to the best of their ability.

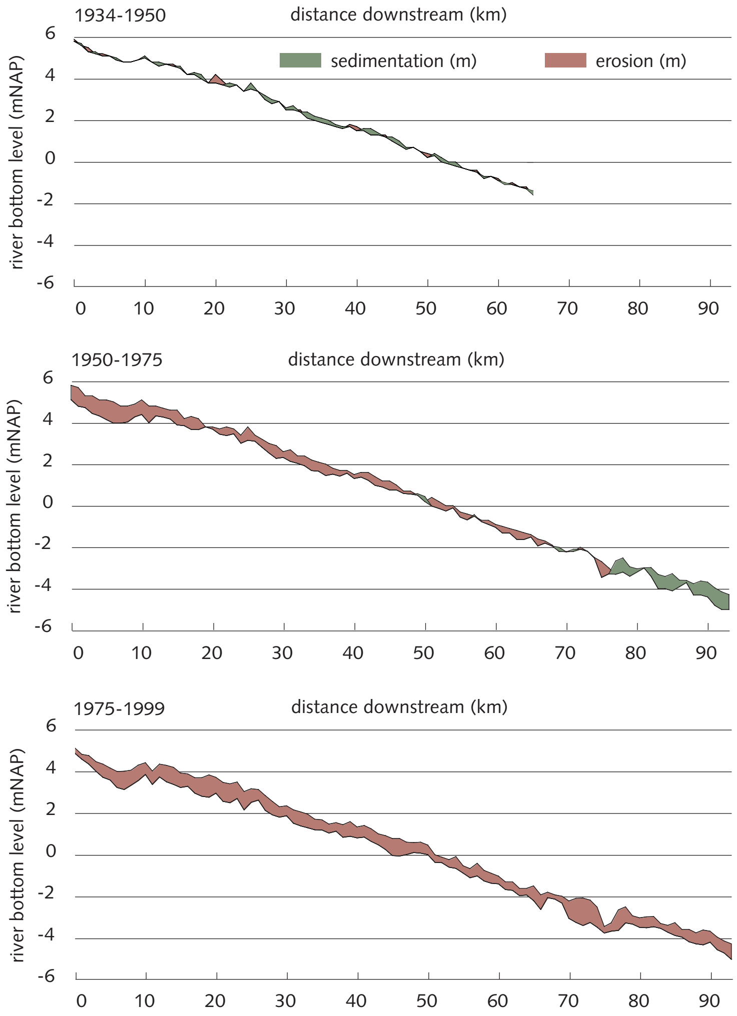
The fight against riverbed subsidence

During the past hundred years, a great deal of dredging has been carried out in the Waal. Gravel and sand were sold as raw materials for building, which resulted in more gravel and sand being removed than the river itself received from upstream. This in turn resulted in the riverbed subsiding lower and lower: between 1 and 3 cm a year on average. River training works have also contributed to rivers cutting an increasingly deeper course for themselves. This riverbed subsidence had all kinds of harmful consequences: construction works such as groynes and bridge piers projected higher and higher from the riverbed and were in danger of being undercut, while gate bars became increasingly elevated vis-à-vis the water level, so that ships had less depth of water to sail in. Groundwater in the vicinity of the river subsided along with the river water level, which dried out the land. Hard clay and peat banks formed along the bottom of the Nederrijn, just across the German border, which formed bars for shipping. Since the 1990s, gravel and sand dredged from rivers has been deposited back in the deeps, such as in the outer bends. This new sand extraction policy is intended to inhibit riverbed subsidence, although other measures will also be required to put a complete stop to this subsidence.



Dredged gravel and sand in the Rhine branches during the last century (m^3/year)





Riverbed subsidence in the Waal in three successive time-spans

SEDIMENT AND FLOODS

Rivers in the Netherlands fan out into different tributaries: this is typical of a delta. In natural situations, the main stream regularly changes course: one tributary silts up, while another attracts more water and erodes its bed more deeply. Geologists have established that during the past 10,000 years (the Holocene period), the Rhine and the Meuse altered their courses once every 100 years on average.

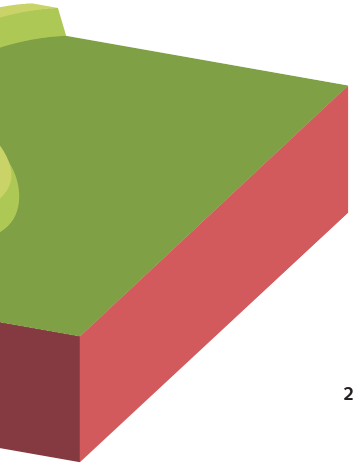
Bifurcation points

The continual changes in the riverbeds make rivers unpredictable with respect to flood protection, shipping, freshwater resources and land use. For this reason, every effort was made in the past to stabilise these bifurcation points and to control the discharge distribution among the tributaries. One important step was the construction of the Pannerdensch Kanaal 300 years ago. This canal has been constructed in such a way that at high tide, about two-thirds of the Rhine water continues to flow through the Waal and the remaining one-third flows along a route to the north. About 10 kilometres further on, the latter part of the discharge is divided once more at the IJsselkop: about two-thirds flows into the Nederrijn-Lek and one-third into the IJssel. These two bifurcation points distribute the Rhine water over the country. Water management in the Netherlands, such as the height of the dykes, the availability of irrigation and drinking water and the prevention of salt water intrusion, depends on this. If silting up or erosion occurs in the vicinity of the bifurcation points, this will directly affect water distribution, and for this reason, such processes are kept under close observation in order to keep the bifurcation points stable.

The location of the two bifurcation points is well-chosen. The smallest tributary invariably branches off at the outer bend of the biggest tributary, which prevents the small tributary from silting up. At the bend of a river, water containing sediment flows from the outer bend to the inner bend. The outer bend is eroded, while the sediment accumulates in the inner bend. Therefore, a bifurcation point in the inner bend would soon become blocked, whereas a bifurcation point in the outer bend maintains its depth of its own accord.

Floodplains, riparian zones and salt pastures

The floodplain along the river is inundated at high tide. Silt plays the star part in these areas: a layer of silt remains behind after each high tide and the floodplain is elevated slightly. This process has been accelerated by dyke construction because silt has been settling in a smaller area ever since. Indeed, the floodplains nowadays are sometimes even higher than the land behind the dykes. The higher the floodplain, the



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2 Circulation of gravel and sand in the Waal. River-basin managers carry out dredging operations in the shallows, the sediment is deposited into the deeps and in due course it flows back to the dredge site.

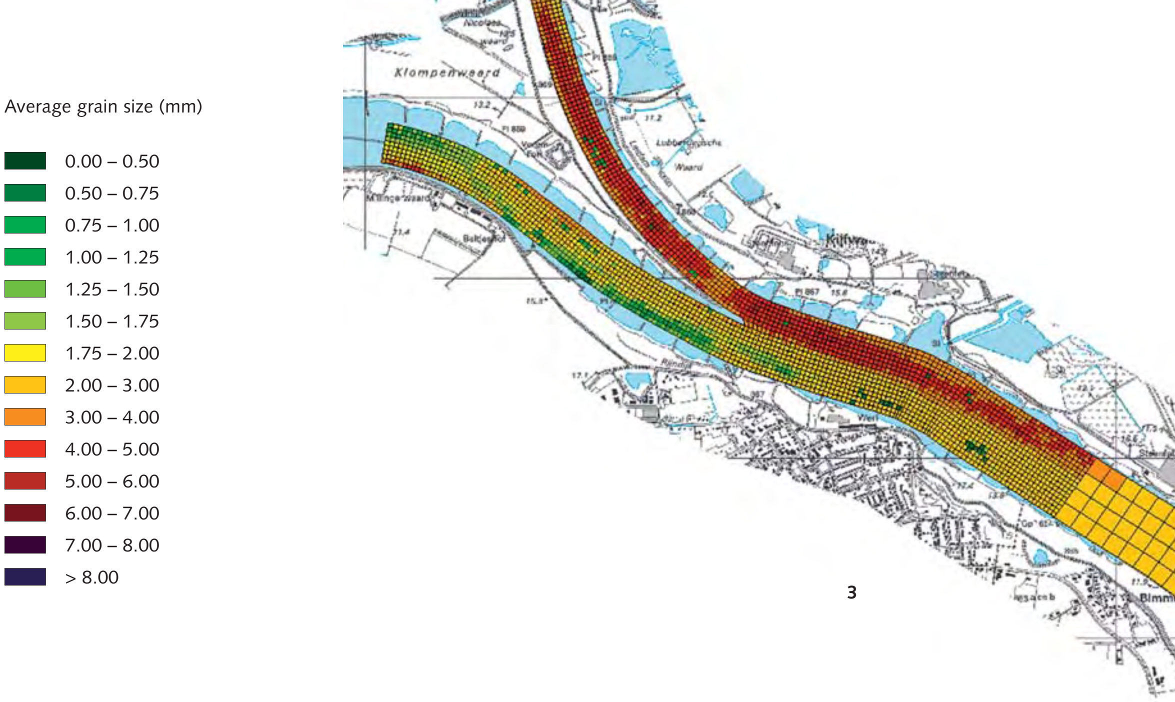
less frequent its inundation, which means that deposition now occurs at a slower rate.

During the next few years, measures will need to be taken to protect the land from being flooded. This can be done by raising the dykes, although it would be preferable to create more space for water between the dykes. For example, more room can be created by excavating a thick layer of the silt accumulated on the floodplains. This would mean that the riparian zones would again be inundated more frequently, resulting in more silt being deposited. The processes would be put back in time, so to speak.

SEDIMENT AND THE ENVIRONMENT

One of the properties of silt is that it can absorb a great deal of pollution. River pollution was at its highest level during the 1960s and 1970s, and silt was given a bad press at that time in consequence. It was synonymous with heavy metals, PAHs, PCBs and all kinds of other unpleasant substances. Part of this polluted silt has remained on the floodplains, but most of it flowed straight through to the Rhine-Meuse estuary, where it settled in the Hollandsch Diep, the Haringvliet or the harbour basins, or was carried out to sea.

3 The coarseness of the sediment on the river bottom at the Pannerdensche Kop bifurcation point. The coarsest sediment is situated in the outer bend, where the Pannerdensch Kanaal branches off from the Waal.
4 Bifurcation point of the Pannerdensch Kanaal.
5 Silt loads from Rhine, Meuse and Waal join up in the tidal river region (figures in millions of tons a year).



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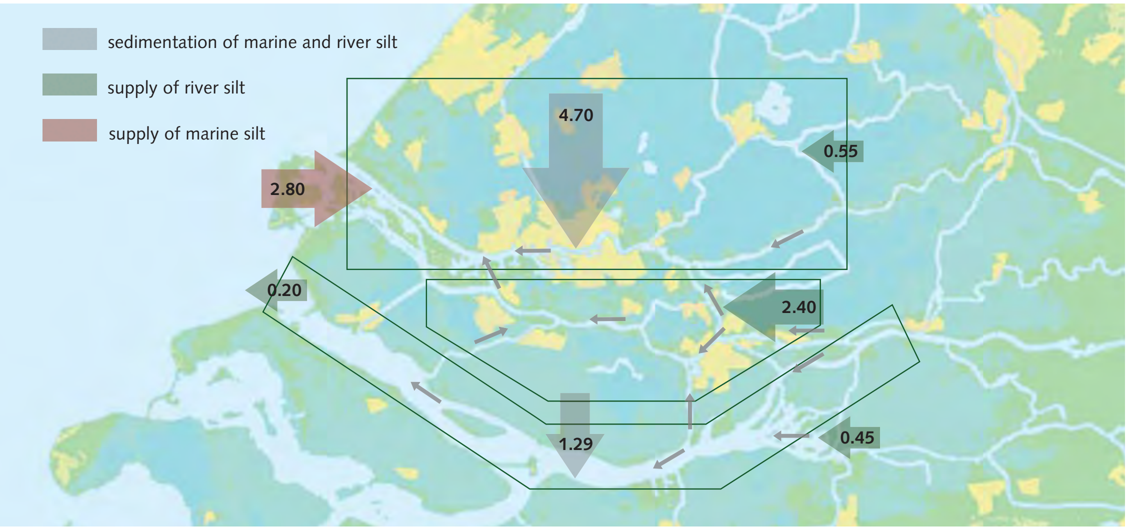
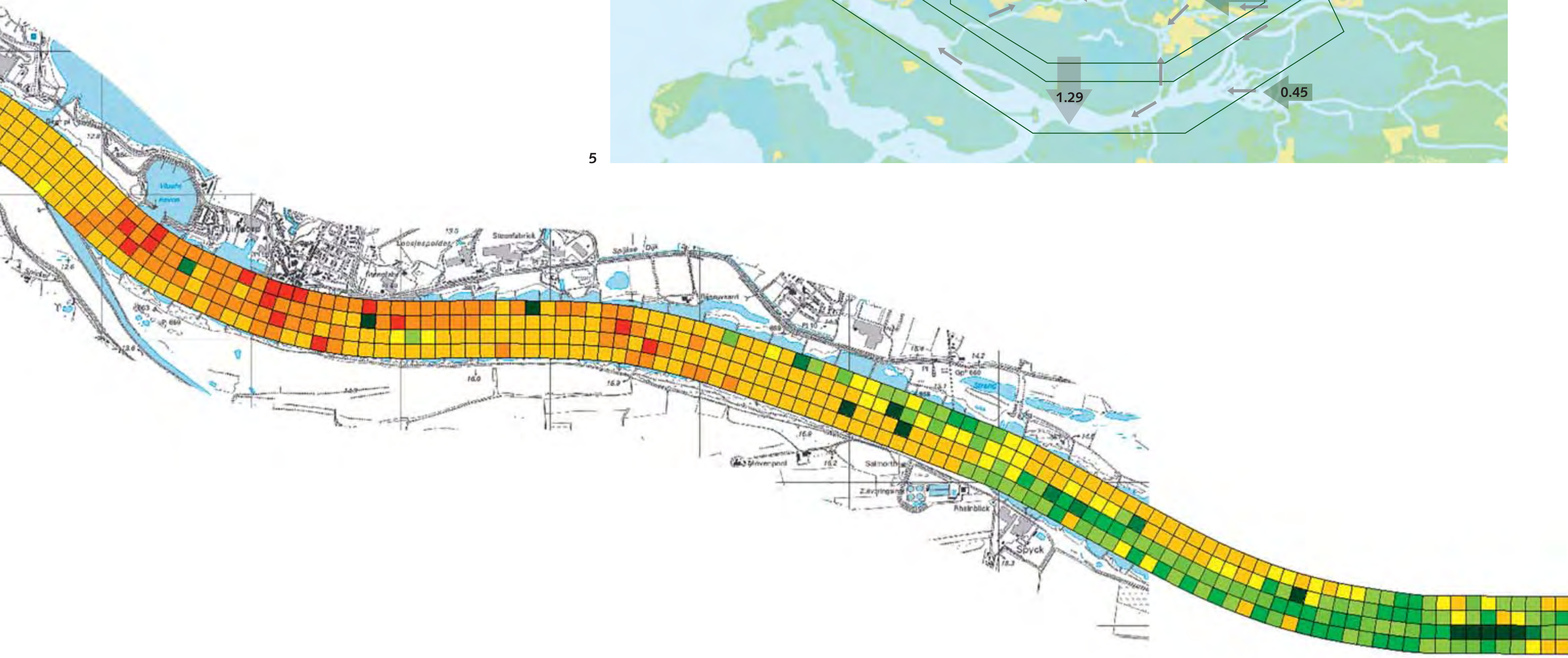
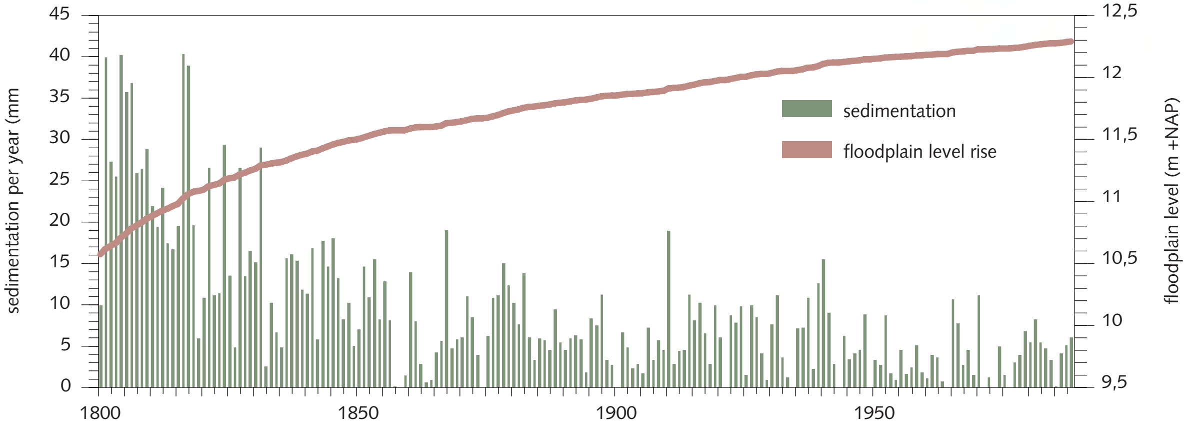


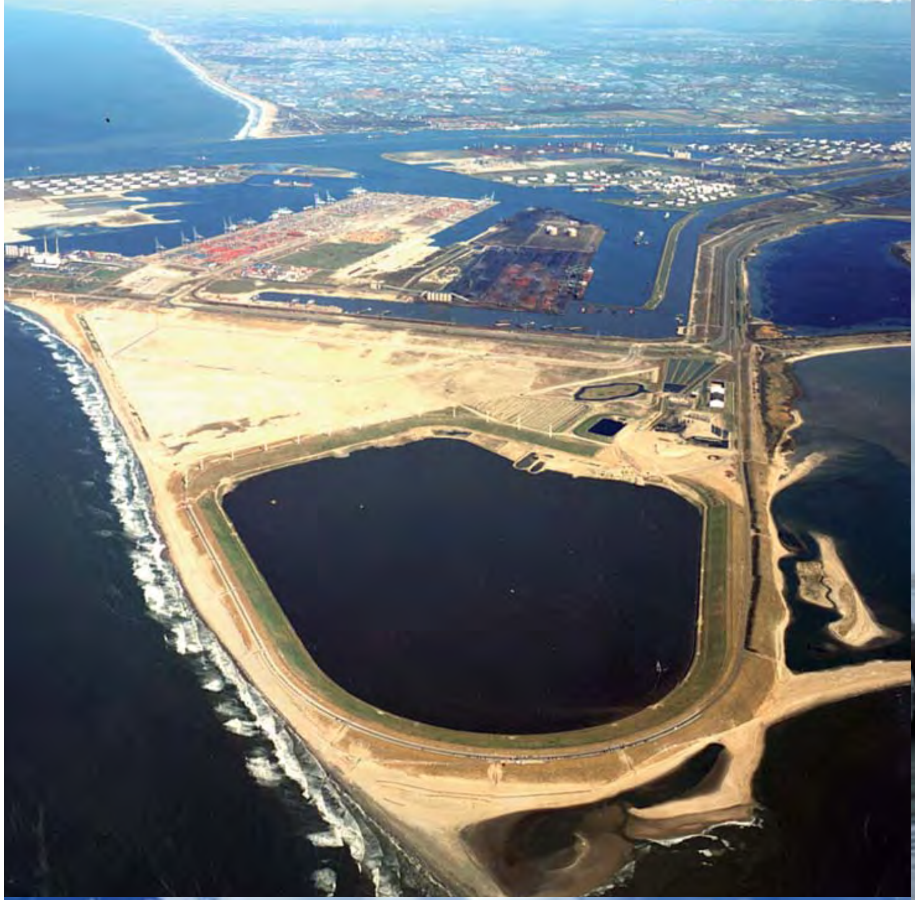




Rising ground level resulting from two centuries of silt sedimentation in the floodplains

Meanwhile, the decontamination of pollution sources has had its effect, since the silt is now a lot cleaner. Deposits of last century's heavily-polluted silt have been covered up with a layer of much cleaner silt. Despite this, it is not completely clean yet; part of the silt released during dredging operations still has to be stored in special basins, and if the floodplains are lowered, the polluted layers of silt will be exposed. This makes river enlargement a costly business.

Due to events in the past, silt is still regarded as being filthy. However, silt also has other, more positive, properties: it makes extremely fertile soil, for instance. In the past, farmers were pleased to see floodplains or riparian zones being inundated, as this left a layer of natural fertiliser on their land. Silt is an important source of food for plants and animals, too, provided that it does not make the water too turbid. Moreover, the unique plant growth on mudflats is actually protected throughout Europe.



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6 Silt storage basin The Slufter in the Maasvlakte… **7** … is a depot for heavily-polluted silt **8** Dredging the waterway **9** Small Fleabane has spread in the riverine area over the past decades, thanks to improved water quality. **10** Muddy riverbanks form a dynamic habitat. In the tidal river areas this is increased by the changing water levels due to the tide.

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Nieuw Bergen
gem Bergen
Tot ziens
ZONE
30

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FLOODS

The water level in the rivers is constantly changing and river flooding is a naturally-occurring event. Throughout history, dykes have played an extremely important part in the battle against flooding. In recent years a new solution has made its appearance: more space for rivers.

Flooding: a danger or an opportunity

People living in the neighbourhood of rivers have been plagued by floods times out of mind. High river discharge was by no means always the cause of such floods: the greatest natural danger here was if a thick layer of ice covering the rivers and floodplains began to break up. If the ice floes slid over one another, gigantic icebergs were created that could easily push part of a dyke out of the way. Ice dams were also able to form on the rivers and the water behind was subsequently backed up. The very first groynes that were constructed in the rivers were intended to prevent this happening; the groynes helped the water to flow faster, which meant it could not freeze so easily.

Nevertheless, at times floods could be used to good advantage. Some people used to breach the dykes on the other side of the river to take the pressure off their own dykes. Breaching dykes was also a popular means of stranding enemy forces in the middle of a large stretch of water; the Dutch Water Line from Muiden to the Biesbosch is the best-known example of this.

The last time that the river dykes were breached was in 1926. This was because a record amount of water was flowing through the rivers at that time: 3,000 m3/s in the Meuse at Borgharen and 12,600 m3/s in the Rhine at Lobith. The worst of the flooding occurred in the Land van Maas en Waal. In 1953, major flooding occurred in Zeeland and the Rhine-Meuse estuary, caused by an extreme storm surge at sea. The Rhine and Meuse waters reached dangerous levels once again in 1993 and 1995; although the dykes just managed to hold together, villages along the Meuse suffered severe flooding.

CAUSES OF FLOODING

Why is the water level sometimes so high in the winter? A great deal of water flows through Dutch rivers if large amounts of rain fall upstream in the rest of the catchment basin. After a long period of rain, the soil in the catchment basin is saturated with water, and the precipitation flows straight into the river. This runoff can make the water level rise at a considerable rate. Since very little water evaporates

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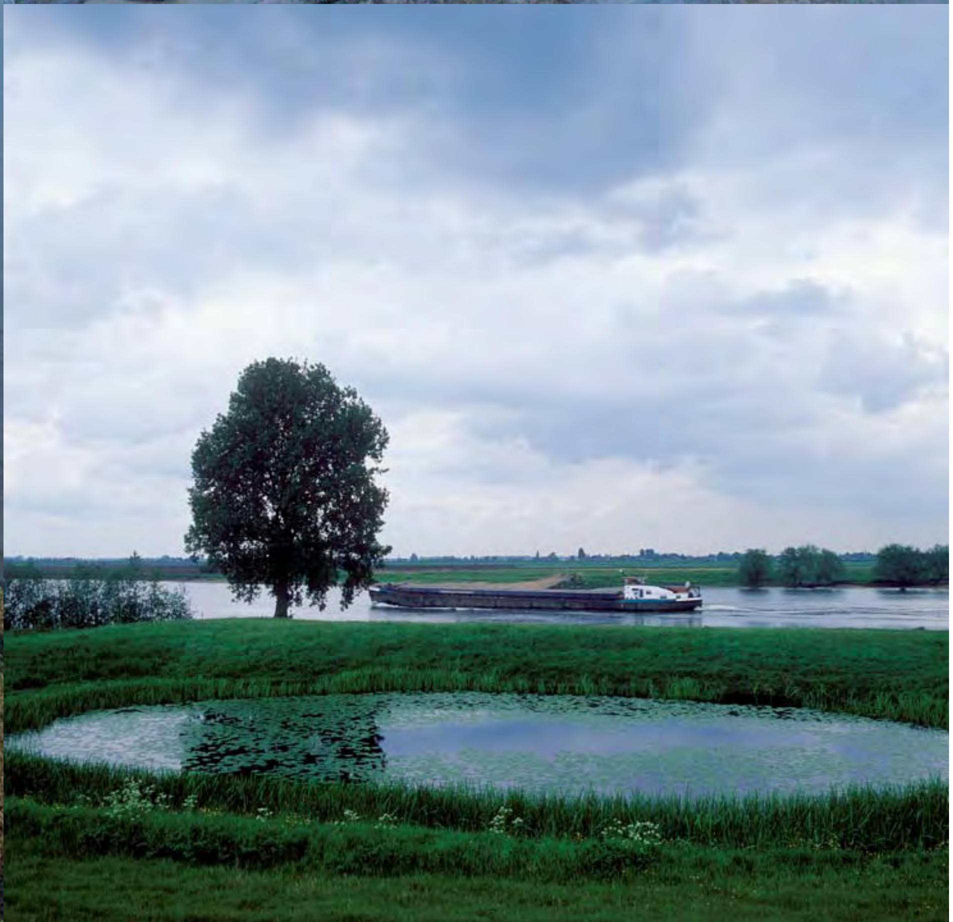

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in winter, the chances of soil saturation - and therefore of flooding - are the greatest in this season. Precipitation is able to enter rivers very quickly, especially when the subsoil is frozen.

When the snow in the Alps melts, water levels in the Rhine in Switzerland and southern Germany can rise considerably. However, the German tributaries have to discharge large amounts of water for the water in the Dutch Rhine tributaries to reach flood level. Under normal conditions, water from melted snow will not result in extreme flooding in the Netherlands. Discharge from the Meuse is almost invariably determined by the capricious precipitation patterns. Since the Meuse's catchment basin is small, a rain front can easily cover the entire catchment basin, and this is why the Meuse's discharge changes much more quickly than that of the Rhine. A flood surge caused by intensive precipitation in the Ardennes will reach the Dutch border the very next day.

The influence of tides becomes increasingly evident as rivers approach the sea. Floods in the neighbourhood of Dordrecht are often a consequence of greater water discharge combined with a storm at sea. The more westerly the rivers flow, the more dominant the sea tides become, while high water levels at sea hinder the discharge of river water. A similar situation can be observed in the IJssel estuary: when there is a north-westerly storm, the IJsselmeer water backs up towards the mouth of the IJssel and thus prevents the river water from flowing out properly. In such cases, this can cause floods in the IJssel delta at Kampen.

Heavy rainfall at home does not greatly affect water levels in the Rhine and the Meuse. Although water in the tributaries and streams can reach high levels, this quantity pales into

1 Flooding of the Waal at Groenlanden (1993)
2 The Oosterschelde storm surge barrier at wind force 10
3 Dyke breaches in the past created deep, circular lakes at many locations. The reconstructed dyke had to go round these lakes.

insignificance compared to the discharge from Rhine and Meuse. If flood levels in the IJssel or the Meuse coincide with flood levels in a tributary, this can cause problems at the mouth of the tributary. This happened in 1995 when the Dommel flooded at Den Bosch. The Meuse water was so high at the time that the water in the Dommel was unable to flow away.

The exact height of the water level at a given spot along the river depends on the local condition of the main channel and floodplain; obstacles prevent the river from flowing smoothly and cause high water levels. Obstacles include such structures as buildings, minor dykes, dyke ramps and groynes. Groups of trees and bushes also slow down river discharge.

Climate change

There are increasingly frequent signs that the climate is changing, and this might well affect river flooding. The national meteorological office, KNMI, is forecasting higher rainfall in the winter and a more rapid rise in sea level. These changes will mean that flooding occurs more often, and flood levels will be higher too.

River discharge, which is the determining factor for dyke height, is expected to increase during the 21st century. At the present moment, this discharge amounts to 16,000 m^3/s for the Rhine, but it may increase to 18,000 m^3/s during the next 50 to 100 years. With regard to the Meuse, discharge is expected to increase from 4,000 m^3/s at present to 4,600 m^3/s during the course of this century.

The increase in sea level in the Zuid-Holland delta also affects flood levels in the rivers. During the next hundred years, the sea level is expected to rise about 60 centimetres, and this will in turn become evident in the flood levels in the Rhine-Meuse estuary. Due to the increase in sea level, the water in the IJsselmeer will encounter more difficulties in running off into the Wadden Sea. This means that the water level in the IJsselmeer will be higher, which in turn will result in more back water in the IJssel delta.

Flood reports

If there is a flood wave moving along the river, Rijkswaterstaat draws up flood reports forecasting how high the water level will be at Borgharen (Meuse) or Lobith (Rhine). The water levels at other locations along the river are then calculated on the basis of these two forecasts. The flood reports are used to determine whether the dyke watch should be called out, for instance, or ferries taken off the rivers and people and animals evacuated.

Flood reporting for the Rhine is initiated if the water level at Lobith is 14 metres above mean sea level (NAP) and is expected to rise to 15 metres above mean sea level. For the Meuse, flood reporting commences if the water level at the village of Borgharen

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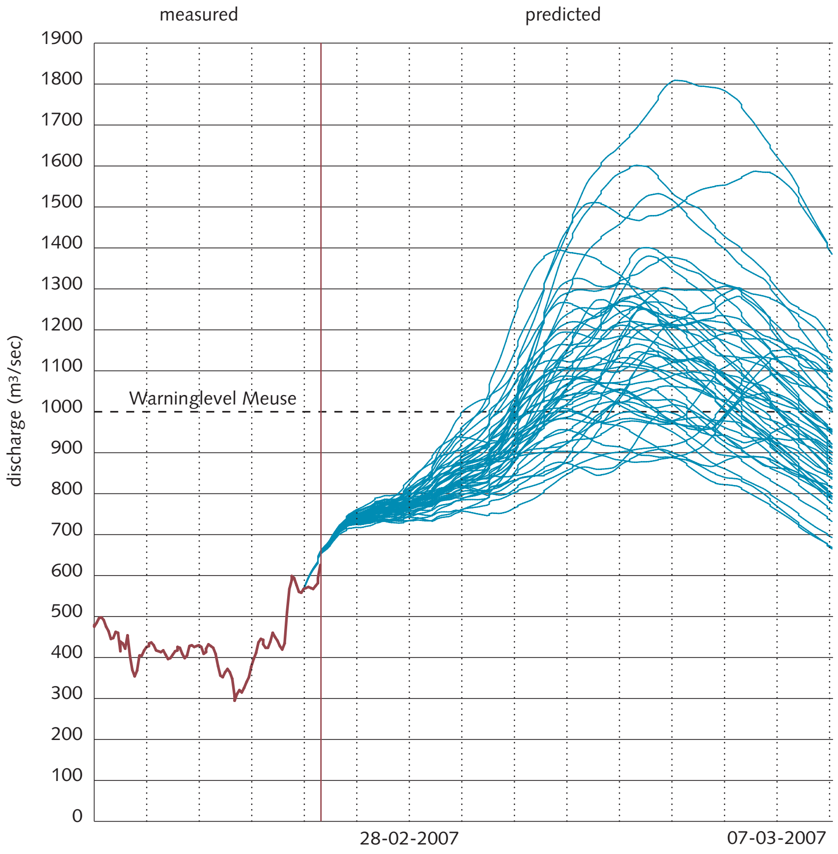
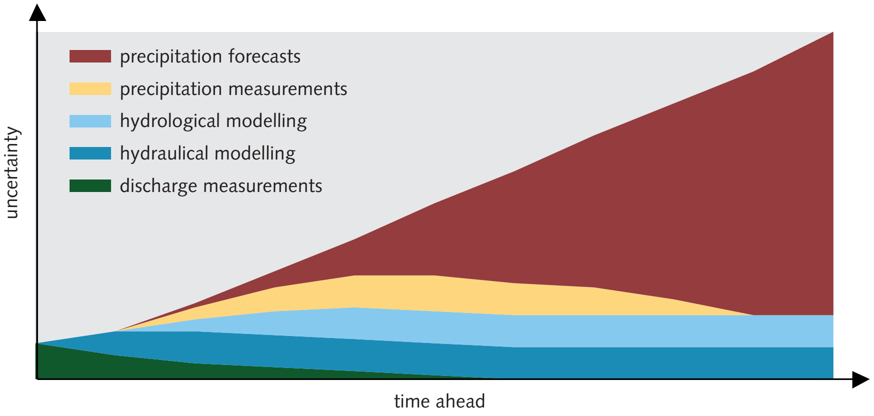


Accumulation of flood forecasting for the Meuse at Borgharen



Several factors contribute to uncertainties at flood forecasting

is higher than 44.10 metres above mean sea level and is expected to rise further. At the start of the flood reporting, Rijkswaterstaat provides information to provincial authorities, water boards, municipalities and auxiliary services, e.g. the fire brigade.

If it is anticipated that the sea level at Hook of Holland will rise as far as 2 metres above mean sea level, the Storm Surge Warning Service will come into action. Rijkswaterstaat makes a forecast for the water level at Dordrecht and other towns and issues a warning to water boards and other interested parties. The water boards will then call out the dyke watch, depending on the gravity of the forecasts. If the water level at Krimpen aan de IJssel is expected to rise to more than 2.20 metres above mean sea level, the authorities will close the storm-surge barrier in the Hollandsche IJssel. The Maeslant and Hartel barriers will be closed if the anticipated water level at Rotterdam is 3 metres above mean sea level, or 2.90 metres above mean sea level at Dordrecht.

The flood reports are available on Teletext (page 720) and on the Internet (www.infocentrum-binnenwateren.nl; www.svsd.nl). These reports are updated twice daily; this is done more frequently in the case of extreme flood levels. In areas where the situation is critical, people are given extra information by the mayor of their municipality and the media. Since 2005, the government has been providing information in times of crisis on a special website, www.crisis.nl: this includes cases of extreme flooding.

Forecasts

Rijkswaterstaat forecasts the flood levels using computer models. The KNMI weather forecasts are an important source of information for the flood level forecasts. Weather is very difficult to predict, since it frequently turns out differently than expected, and this uncertainty makes itself felt in the water-level forecasts. The more long-range the forecasts, the more uncertain the calculations.

Rhine water levels for the following day can be accurately predicted to within 10 centimetres. This means that the water level may be 10 centimetres higher or lower than the level which has been forecast. Forecasts for the second day can be accurately predicted to within 15 centimetres, and 20 centimetres for the third day. For subsequent days, Rijkswaterstaat is only able to forecast whether the water level will rise or drop. Rijkswaterstaat makes less long-range forecasts for the water level in the Meuse than for the water level in the Rhine. The reason for this is that the catchment basin is smaller, which is why the water levels in the Dutch part of the Meuse are extremely quick to react

4 Flooding of the highway A2 (Den Bosch 1995) **5** The information-and warning centre in Lelystad provides flood warnings at high discharges.

to heavy rainfall upstream. The precise effect on water levels depends on a number of factors, including whether the soil is already saturated with water, and how the weirs in southern Belgium are operated. All this makes it hard to give an accurate forecast. Forecasts can give an indication of how high the water will be 12 hours later at Borgharen with an accuracy of between 15 and 25 centimetres.
Countries situated along Rhine and Meuse cooperate closely with one another. Those countries situated along the upper reaches warn their neighbours downstream as soon as they see a flood surge coming, and they also exchange the latest data on precipitation and discharge.

SAFEGUARDING AGAINST FLOODS

Flood Defences Act

Dykes, dunes, dams or storm-surge barriers are situated along almost all large bodies of water in the Netherlands to provide protection against flooding. In the 1996 Flood Defences Act, these are referred to as primary water-control structures. Also known as levels of protection, they are required to comply with legal requirements.

Various different requirements apply in the riverside areas, and the strictest standards apply to the coast. The chance that the water level along the coast will be higher than the water level on which the water-control structure is based must be smaller than 1/10,000 per annum. Looking at this from a long-term perspective, this comes down to an average of once every 10,000 years, although of course this could also occur twice within a short space of time. This standard is so stringent because a storm surge at sea cannot be predicted very easily, and under normal conditions evacuation would not be possible. Moreover, flooding by saline sea water would cause a tremendous amount of damage. In addition to this, the coast of the Randstad area is densely populated, and its economic value is high. Following the course of the rivers inland, this standard gradually decreases as the water becomes fresher and the influence of the river increases. This is because flooding on rivers can be forecast several days beforehand, which enables residents to be evacuated if the situation gets too dangerous.

Rijkswaterstaat determines which requirements the water-control structures must comply with in order to be able to provide the level of protection which the law demands. These requirements are updated every five years because the qualifying water discharges may alter during the course of time due to factors such as climate change. In addition, Rijkswaterstaat has to ensure that the riverbed is maintained properly so that no unexpected back water can accumulate in the meantime. In general, water boards are responsible for maintaining the primary water-control structures. Every five years, they check whether the dykes meet the requirements, and the provincial authorities report the results to the Minister of Transport, Public Works

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and Water Management. If a dyke does not comply with the standard, it is essential that measures be taken such as dyke improvement or widening of the riverbed.

"Water boards are the proper organisations to maintain the dykes and reinforce them if necessary. During the past years, we've learnt to adopt a different approach to our work than in the past, by giving more attention to nature, cultural history and the landscape. As far as the natural landscape goes, it's far better to cover the dykes with a mixture of grasses than to use one single variety. We've also discovered that using different species of grass in the dyke covering also gives a great deal of protection against erosion.

During flooding, the water board has to check whether the dykes will hold, and it must solve any problems quickly if necessary. Old-fashioned sandbags are still fine to use here, although there are fortunately more modern means at our disposal nowadays. This task of the water board is important, but it is also difficult because it's hard to get practical experience. And when all is said and done, training exercises are quite different to working during real floods. We had to improvise a lot during the 1993 and 1995 floods, and we managed to do what was needed reasonably well. But we did learn that we have to be even better prepared, and we now have flood scenarios readily available, among other things. If a dyke were to burst at Weurt, for instance, we know right away which places will be flooded and in what order. Information like this is important when safety regions need to organise evacuations.

I've been working for various water boards since 1969. At that time, water boards primarily maintained a 'wait and see' attitude: the national authorities drew up the policy and the water boards subsequently enforced it. Nowadays, water boards provide cooperative input on new developments in collaboration with the other stakeholders. What I like about water boards is that we are directly in contact with all the stakeholders. If we reinforce a dyke, this means a change in people's environment, and this can and should be taken into consideration."

Bas de Bruijn, Rivierenland Water Board

Dykes, dams and storm-surge barriers

Dykes are not necessary in every part of the riverside area, since the land surrounding the rivers is naturally elevated in some places. An example of this is the Nederrijn at Wageningen, where the river flows close by a lateral moraine. The Meuse in Limburg is not entirely dyked either, since the banks of the river themselves form a gentle slope. Nevertheless, the villages bordering the river are affected by flooding from time to time, and for this reason, embankments have been built around the more vulnerable areas in the Meuse valley, while the land along most of the other parts of the river is occupied by low-lying polders. If a flood occurs, the water in this kind of polder can reach a height of several metres in a very short time. This is dangerous and can cause a great deal of damage, so it is very important that these areas are securely dyked.

6 Dyke reinforcement along the Waal **7** The Grebbenberg forms a natural "dyke" for the Nederrijn at Rhenen. **8** Filling of the floodplain along the Lek.

A storm surge at sea poses the biggest threat of flooding near river estuaries. After the 1953 flood disaster, a great many sea arms in the delta were closed off in order to keep the sea at bay, and the Haringvliet dam was constructed in the Haringvliet estuary as part of the Delta Works. The tide in the Haringvliet and the Biesbosch has decreased considerably as a result. The dam is equipped with sluices; part of the Rhine and Meuse water flows through these sluices to the sea.

The Nieuwe Waterweg waterway at Rotterdam has not been closed off by a dam, since this would obstruct shipping going to and from the Port of Rotterdam. Three storm-surge barriers have been built to decrease the influence of storm tides; these are only closed if the water level is extremely high. Although dykes are still essential inland from the storm-surge barriers, they do not have to be so high, and this saves money and space. The very first storm-surge barrier in the Netherlands was constructed in the Hollandsche IJssel in 1958. This barrier prevents high storm tides from posing a threat to the low-lying, densely-populated Gouda area. In 1991, it transpired that the dykes along the Nieuwe Waterweg and the Nieuwe Maas were too low. Dyke improvement is extremely expensive in this area and there is very little space for such improvement. For this reason, two storm-surge barriers have been built there: the Maeslant barrier in the Nieuwe Waterweg and the Hartel barrier in the Hartelkanaal. The Maeslant barrier is a really impressive structure, comprising two gigantic steel arms on the banks of the Nieuwe Waterweg that close off the waterway completely at extreme floods.

Gales from the north-west drive the IJsselmeer water into the IJssel estuary, the Zwarte Water and even as far as the Vecht, and can result in extremely high water levels there. The Ramspol inflatable dam has been built at the entrance to the Zwarte Meer lake in order to afford protection for towns such as Zwolle and Genemuiden. This inflatable dam consists of three enormous flexible pipes that automatically fill with air and water at floods, thereby keeping the water at bay. As extra protection, a flood gate has been constructed in Zwolle city centre.

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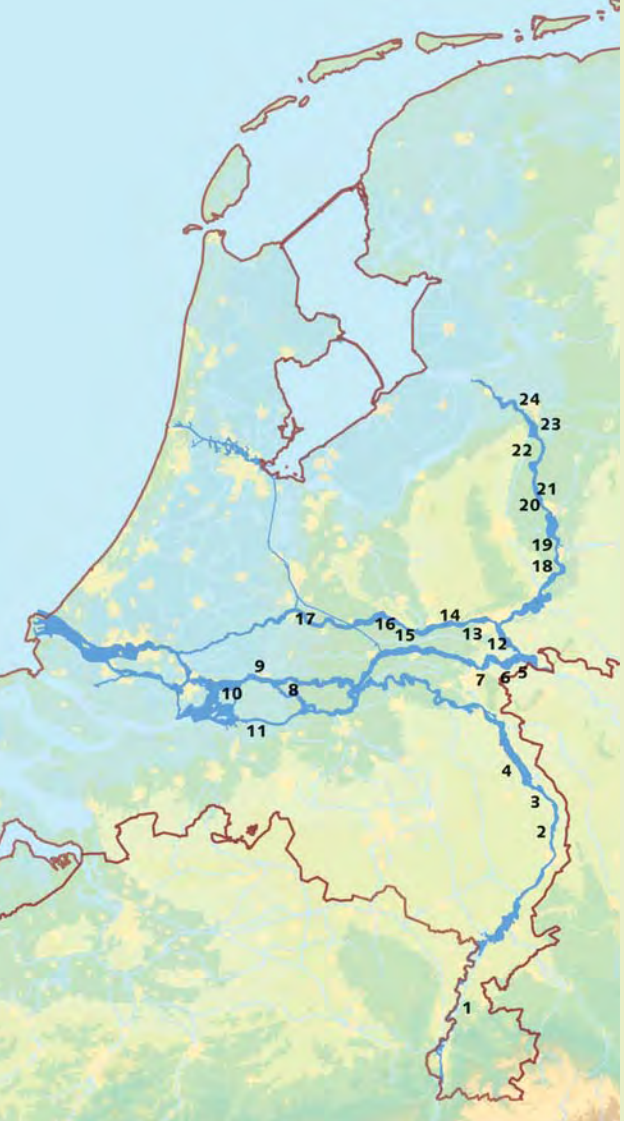

1 Large-scale river widening + laying of secondary channels Grensmaas
2 Flood channel Lomm
3 Flood channel Well-Aaijen
4 Test projects eroding banks
5 Extra floodplain excavation Millingerwaard
6 Removal of obstacle Suikerdam and Polderkade to the Zandberg
7 Putting back of dyke at Lent
8 Floodplain excavation Brakelse Benedenwaarden and repositioning of dyke in Buitenpolder Het Munnikenland
9 Floodplain excavation Avelingen industrial estate
10 Depolderisation Noordwaard
11 Depolderisation Overdiepsche Polder
12 Floodplain excavation Huissensche Waarden
13 Floodplain excavation Meinerswijk
14 Floodplain excavation Doorwerthsche Waarden
15 Floodplain excavation Middelwaard
16 Floodplain excavation Tollewaard
17 Floodplain excavation Honswijkerwaarden, barrier island Hagestein, Hagestein floodplain and Heerenwaard
18 Repositioning of dyke Cortenoever
19 Repositioning of dyke Voorster Klei
20 Floodplain excavation Bolwerksplas, Worp and Ossenwaard
21 Floodplain excavation Keizerswaarden, Stobbenwaarden en Olsterwaarden
22 Flood channel Veessen-Wapenveld
23 Floodplain excavation Scheller and Oldeneler Buitenwaarden
24 Repositioning of dyke Westenholte

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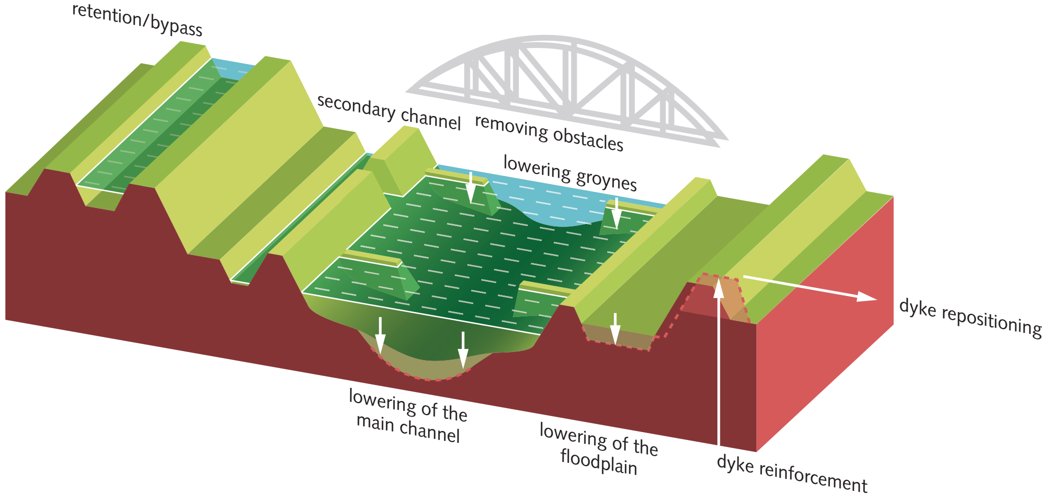

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More room for rivers

Rivers have had to surrender more and more space during the past centuries: dykes were constructed closer to the rivers, and their courses have been straightened here and there. This means that flood waves can move along the river more rapidly, which in turn pushes up the water levels. Sand and silt settle in increasingly smaller floodplains, thereby accelerating elevation; floodplains have also been levelled here and there in order to build homes or industrial estates. All these developments have resulted in less room on the riverbed for conveying high river discharge, and for this reason, a new policy trend was introduced in the 1990s whose motto was ‘room for water’.

Many dykes in riverside areas no longer comply with the safety standards. This is because the extremely high discharges in 1993 and 1995 changed the statistics. The new calculations made after this change indicate that the dykes need to be able to cope with higher water levels in order to meet legal requirements. There are two options for improving safety: either heightening the dykes or widening the riverbed so that it can carry more water. Although the government has resolved to make more room for rivers and to improve the dykes only in exceptional cases, space is a scarce commodity in the Netherlands. More space is also needed for other purposes such as new homes, industrial estates and scenic areas, so room for rivers is hard to come by. Use of space often has to be cleverly combined, which requires comprehensive consultations between all the parties involved.

The measures necessary for widening the rivers have been elaborated in two major projects: the Maaswerken project for that part of the Meuse which is not dyked, and the

9 Dyke reinforcement with sand bags (Waal at Ochten, 1995).
10 The inflatable dam at Ramspol during a north-westerly storm (2006) **11** A selection of landscaping measures with spatial impact, that are actually planned along Rhine and Meuse. (www.ruimtevoorderivier.nl and www.maaswerken.nl). In addition groynes will be lowered along the Waal, obstacles removed and the main channel will be dug out at some locations. Along the Meuse flood water will be retained in some retention areas.
12 Landscape measures creating room for the river Rhine and Meuse. Dyke reinforcement is only applied as a last resort.

'Room for the River' Spatial Planning Key Decision for the Rhine tributaries and the dyked parts of the Meuse. Information on these projects may be obtained from the following websites: www.ruimtevoorderivier.nl and www.demaaswerken.nl. During the next ten years, the water level in the Waal will be decreased by making the groynes lower. The dyke at Nijmegen will be shifted further inland in order to widen the river. A large number of floodplains along the IJssel will be lowered; much of this will be done in combination with nature development, such as creating shallow secondary channels in the floodplains. Plants and animals native to riverside areas prefer this kind of environment to a deep main channel with a great deal of shipping passing to and fro. Banks along the Meuse will also be lowered and planted with indigenous vegetation. Shallow gravel extraction in the Grensmaas in Southern Limburg, amongst other locations, plays a significant part in widening the river because this provides room for water and nature as well as money to finance the project. At the Rhine-Meuse estuary, the river will be given more room at the Overdiepse Polder and the Noordwaard, which will considerably reduce the flood level in the Bergsche Maas and the Boven Merwede.

River widening is a drastic and costly measure. And rivers will need even more room in the future because water levels are expected to rise as a result of climate changes. This is why it is important that such room as still exists does not get used up unnoticed, for example by building on it, and it is also why the Major Rivers Policy sets conditions governing construction in the floodplains.

And if things do go wrong...

Even if the dykes are high and strong and the rivers are given more space, we cannot entirely preclude flooding, and inundation in a flat and low-lying country like the Netherlands can cause tremendous damage and result in a great many victims. Therefore, fast action is essential in order to restrict the consequences of a possible flood. The authorities are preparing for this by formulating strategies known as contingency plans. These plans describe what action the authorities should take, what resources would

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be needed, and how to inform the people and evacuate them if necessary. Training and practice drilling form an important part of this preparation.

If a disaster hits a small area, the local mayor will coordinate the combating of the disaster, as well as relief assistance. In the case of a disaster covering several different municipalities, the Queen's Commissioner or the auxiliary services cooperative (the safety region) will take over the coordination; this will most likely be the case if a flood occurs in the riverside areas. If the disaster threatens to affect the entire country, the coordination will move up a step further to the Minister of the Interior and Kingdom Relations (BZK).

The floods of 1993 and 1995 served to emphasise the fact that they will always pose a threat. And the floods in New Orleans in 2005 have once more demonstrated the extent to which water can disrupt society. The Dutch government is currently investigating whether it might be necessary to resume one of our forefathers' traditions: the construction of partition dykes. These dykes are not situated directly on the rivers but a little farther away, and they divide up the area that might be flooded into smaller compartments. In this way, the damage caused by any dyke bursts will remain within limits. The government has also reserved part of the Beerse Overlaat along the Meuse for possible future use as an emergency overflow area. If the water reaches extremely high levels, it can flow into the emergency overflow area in order to spare densely-populated areas. However, it has transpired that emergency overflow areas along the Rhine are not sufficiently effective, and the government is currently investigating other emergency measures.
If it becomes necessary to combat a disaster, it is of the utmost importance that all parties concerned have the same information at their disposal. For this reason, the

13 In the Stokebrandsweerd, room for the river is combined with nature development and recreation. The extracted clay is applied elsewhere for dyke reinforcement. The project is being carried out by a private landowner. **14** Filling of sand bags in the streets of Blerick (1995) **15** Military assistance during floods on the Meuse (2003)

Flood Information System (HIS) has been devised, which all parties can consult on the Internet. During floods, this system provides information on the water level (both current and forecast), weak points in the water-control structures, and the damage that might occur if the water-control structure collapses at one of these points. The authorities involved will be able to see the effects of the measures they intend to deploy to restrict the potential damage.

Improving the safety chain

Safeguarding against flooding is a chain which comprises a number of links varying from proaction to aftercare. During the past few decades, the Netherlands has mainly invested in prevention through dyke improvement and river widening. Looking at measures taken by other countries, it has transpired that a great deal of benefit can also be obtained from the other links in the chain: Japan, for instance, specialises in proaction. The densely-populated Japanese coast is frequently ravaged by floods, which is why building projects are designed in such a way as to allow the water to flow away easily. The dykes, too, are much wider than in the Netherlands, so that they can be used as terps, or raised plots, for houses as well. The USA mainly invests in combating disasters; since it is almost impossible to take precautions against the severe hurricanes that sweep the country every year. Fast evacuation and fast repair of damage is the best way to deal with such disasters. The Netherlands is using the experience gained in Japan, the USA and other countries to reinforce the safety chain.

Links in the safety chain

1. proaction: taking vulnerable spots into account with regard to flooding, when planning the layout of the area;
2. prevention: preventing floods from occurring, e.g. by constructing dykes;
3. preparation: preparing for a flood disaster, e.g. setting up a calamity organisation and drawing up contingency plans;
4. response: if things do go wrong, taking fast action to keep the number of victims and the damage to a minimum, deploying the armed forces to evacuate the people, pumping off water;
5. aftercare: ensuring that the land can quickly regain its functions after a flood disaster, compensation for damage, giving psychological aid.

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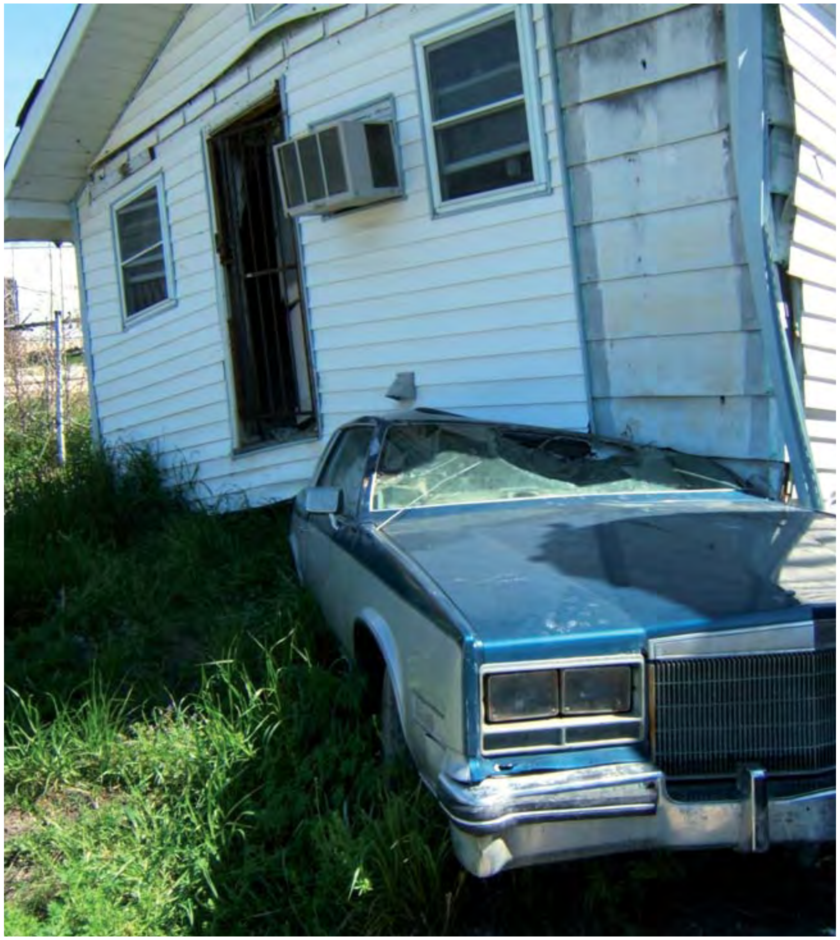

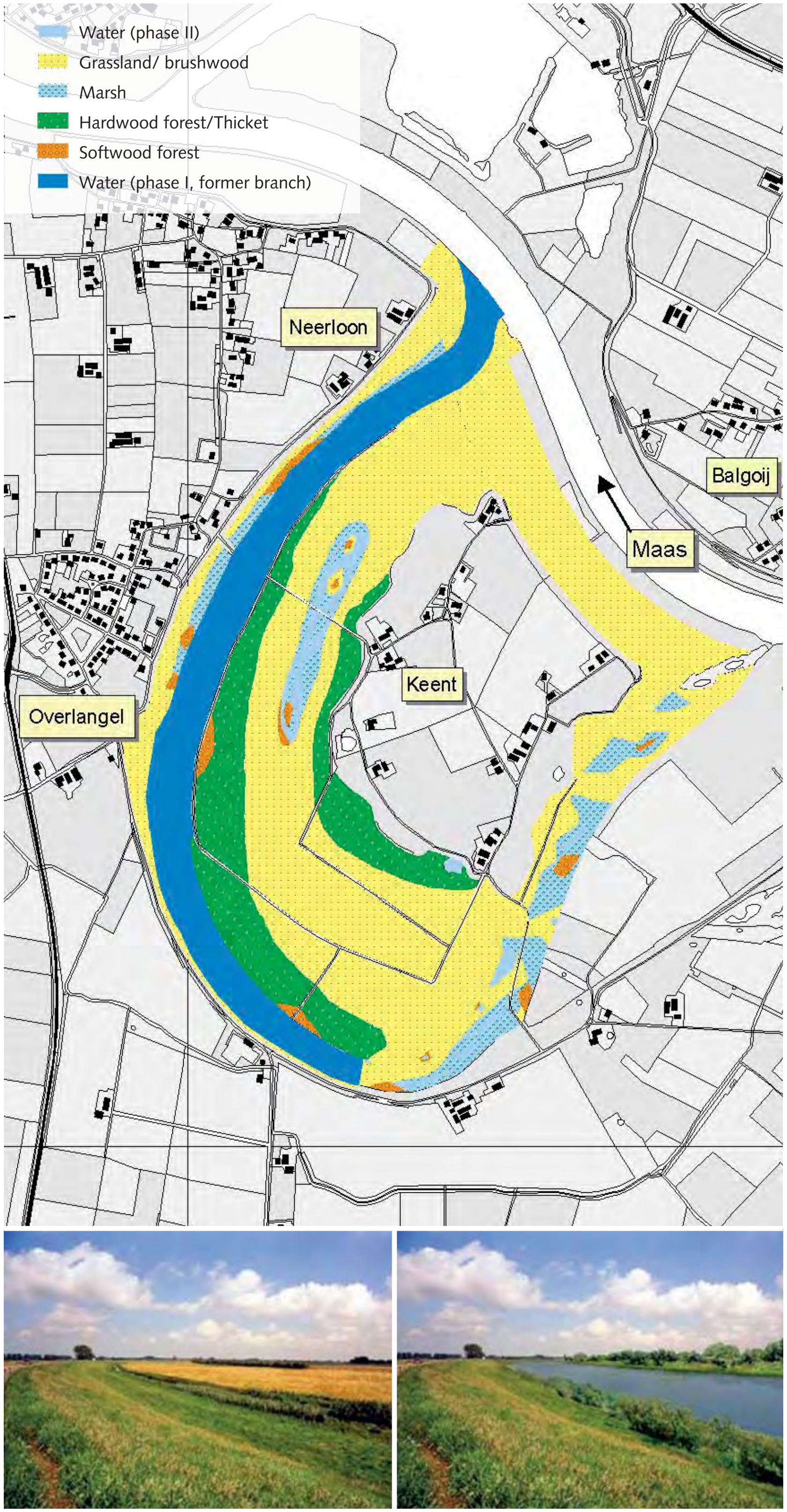

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Cooperating in the catchment basin

Water does not keep within national borders. This is why cooperation with the other countries in the catchment basin is of the utmost importance with regard to safeguarding against flooding. These countries exchange measurement data during floods in order to make forecasts. As a result of the flooding in 1993 and 1995, international plans of action for Rhine and Meuse have been drawn up. The implementation of these plans of action is the responsibility of the International Commission for the Protection of the Rhine (ICPR) and the International Commission for the Protection of the Meuse (ICPM). All countries in the catchment basin are represented in these commissions (for information please see www.iksr.org and www.cipm-icbm.be).

Acting on the initiative of a number of countries, including the Netherlands, the European Union has compiled a European Flood Directive. The purpose of this new directive is to enable countries in one catchment basin to work together to map out the flood risks and to adopt measures to reduce the adverse consequences of flooding. To this end, the countries involved will draw up catchment basin management plans comparable to those governing water quality laid down by the EU Water Framework Directive.

The countries situated along the Rhine and the Meuse also cooperate with regard to increasing their knowledge concerning flooding. Some examples of this are the German-Dutch study on maximum Rhine discharge, and the Dutch-Belgian investigation into the consequences of extremely high discharges for the Meuse. Countries exchange know-how and experiences when preparing and implementing flood-protection projects combined with nature development or mineral extraction (please see www.sandproject.nl and www.sdfproject.nl).

Collaboration in the Dutch part of the catchment basin is also of great importance. It has been agreed that all the different Dutch water managers shall refrain from shifting water-related problems on to one another. For this reason, when seeking solutions to problems posed by flooding, the first choice would be to retain water in its own area, e.g. by ensuring that rain can easily be absorbed into the soil. The second choice would be temporary storage of water, e.g. in retention or water storage areas. In order to take the pressure off water lying further downstream, transport of water to the neighbouring water management area is the last option on the list. It has transpired in practice that application of the retention-storage-transport trio does not always enjoy the support of the people, nor does it always provide the most cost-effective solution. Each case should be individually approached, accompanied by in-depth consultations with all the parties involved. Non-shifting and water retention are important key principles in the international catchment area too.

16 New Orleans, 2006 **17** At Keent the main part of a former Meuse branch is dug out. This creates room for the river during floods. At the same time there is more room for nature development.

"The Meuse and its tributaries flow through France, Germany, Luxembourg and Belgium. This means that international cooperation is very important with regard to managing the Meuse, but we still don't devote enough time to this point. I'm wondering whether this is in proportion with all the national agreements. However, some progress has been made during the past 10 years: we've joined forces to improve the models for forecasting water levels, for instance. But there's still room for a lot of improvement!

It takes a great deal of energy to cooperate with other countries; there are cultural differences and language problems which have to be dealt with. We ought to invest even more in international team building and relationship management. I've noticed that this kind of investment pays off in my own day-to-day management. When there was a shipping accident at Borgharen, the hydro-electric power station at Liège stopped the water discharge at our request so as to enable us to search for victims in the Grensmaas. We were able to arrange this because we know each other personally. And the Maastricht water district is in contact practically every day with its neighbour on the other side of the Grensmaas. That's how I like to see things run.

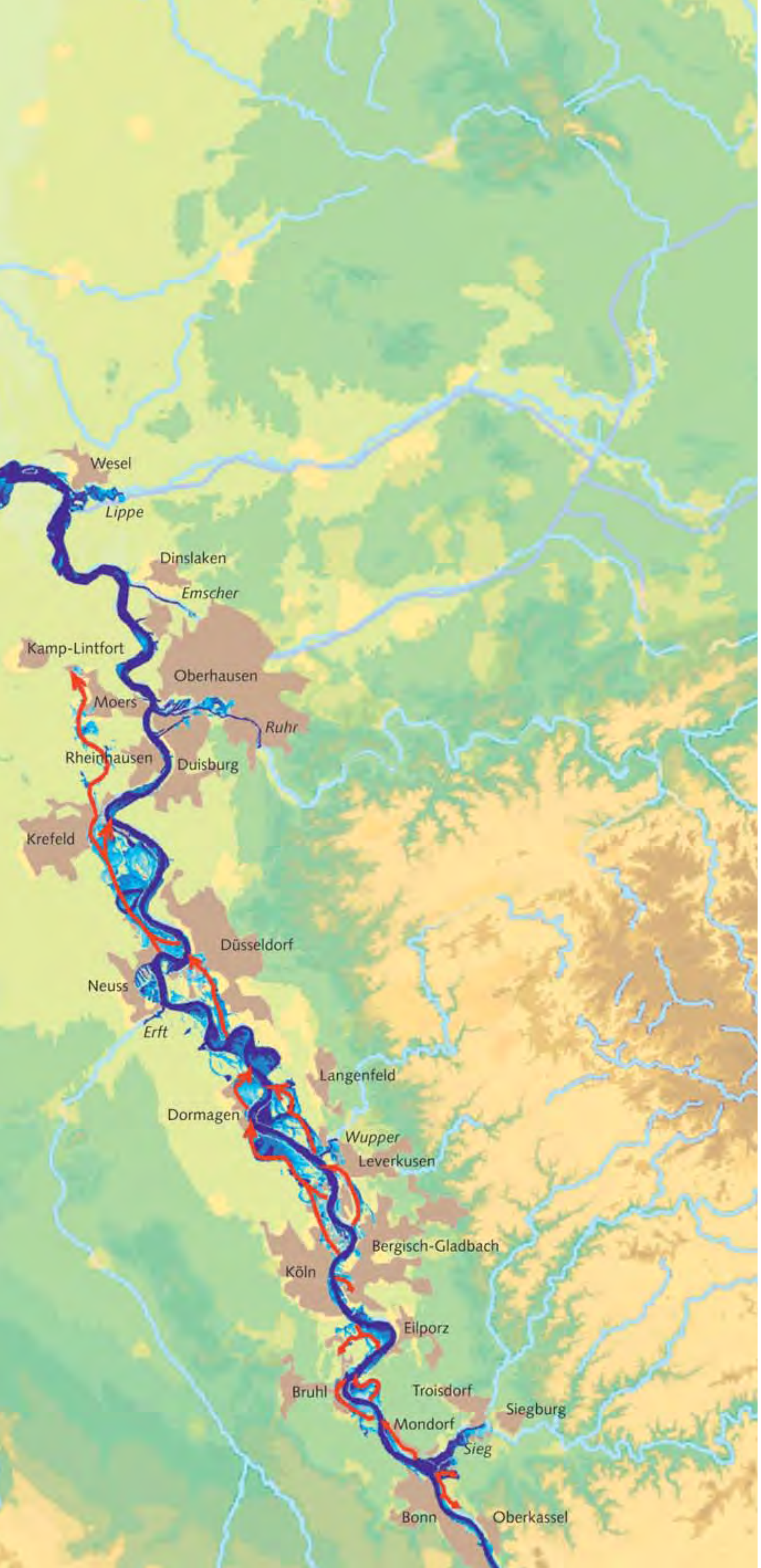
The Integrale Verkenning Maas steering group has advised us to collaborate with the other countries to see whether the flood problem in the Netherlands can be reduced using measures in these other countries. This is my ideal as far as catchment basin management is concerned: working together to see where investment in flood protection would be the most effective. And as far as I'm concerned, the same goes for all other aspects of water management. In 2015, the European Water Framework Directive and the Floods Directive will be running parallel to one another, and that means we will be making integral management plans for water quality as well as safety for the entire international catchment basin. It will be great if this all succeeds, a real dream come true!"

Eric Marteijn, Director of Water and Shipping, Rijkswaterstaat Limburg

Niederrhein (Lower Rhineland) study

The Netherlands and the German state of North Rhein-Westphalia have been cooperating intensively on flood protection along the Rhine since 1997. In 2004, they carried out a study to find out the maximum amount of Rhine water that could flow down to the Dutch border. If extremely large amounts of precipitation fall in the Rhine catchment basin, this could apparently result in very high discharges: higher than any measured up to now. It is certainly possible that the maximum amount of discharge that the Dutch dykes have been built to handle could in fact reach the Netherlands. As things stand at present, no extra discharge needs to be calculated because in such a situation flooding would have already occurred in Germany. However, if the climate does change in the future, and Germany is better able to protect itself against flooding, the maximum discharge that can reach the Netherlands may possibly increase.

If flooding occurs in Germany, the superfluous water may get as far as the Netherlands in some cases...but on the wrong side of the dyke! Although the chances of this happening are very slight, the Netherlands and Germany are currently working together to examine possible measures to be adopted by both countries in order to reduce the danger of flooding still further.



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18 Areas in Germany that are flooded when dykes turn out to be too low at extreme flood events. Red arrows indicate spreading of the water behind the dikes.
Source: Gudden, J.J. (2004): Grensoverschrijdende effecten van extreem hoogwater op de Niederrhein, deelrapport Overstromingen in Nordrhein-Westfalen en Gelderland. ISBN 9036956692.

6

LOW FLOWS

Most of the time there is sufficient water for all users. However, after a warm dry period the water level in the river drops. Regulations for water distribution ensure that those functions most at risk are given priority.

CAUSES OF LOW FLOWS

An average of 2,300 m^3 of water per second flows through the Rhine and 230 m^3 per second through the Meuse. Water shortage problems arise when discharges are below 1400 m^3/s for the Rhine (measured at Lobith) and below 130 m^3/s for the Meuse (measured at Liège). Weirs in the Meuse and the Nederrijn-Lek ensure that the water level remains high, even in the case of low flows.

Low flows primarily occur in summer and early autumn. Mean precipitation displays little seasonal variation. The seasonal discharge variation reflects the variation in evapotranspiration. High evapotranspiration causes a decrease in the moisture content of the soil, which results in an increase of the water-storing capacity of the soil. During summer, the discharge of the Rhine and Meuse are largely derived from water releases from groundwater storage, and in the case of the Rhine, from melted snow. The aquifers and snow supplying this water are mostly recharged during the winter season. The increase of winter precipitation will therefore reduce the occurrence of low flows to a certain extent.

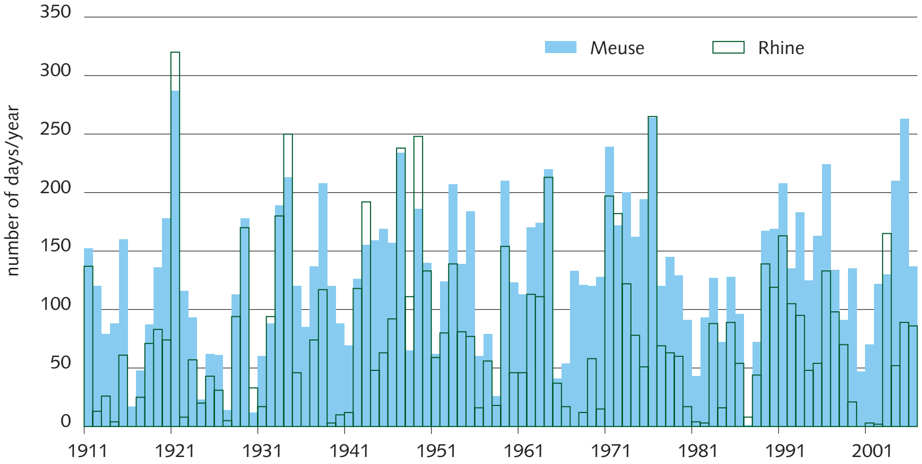
Low flows can also occur during winter. Freezing may partly stop the flow of water in the upstream catchments. Moreover, if frost occurs, the weirs in the river are opened to prevent them from freezing and also to prevent the formation of ice dams. The water level along the canalised stretches of the river then drops rapidly. This happens only rarely these days because the water temperature in Rhine and Meuse has risen (mainly as a result of the discharge of cooling water).

Low flows can occur in the Rhine-Meuse estuary if there is a prolonged east wind. There is seldom any shortage of water here because the tide always provides sufficient water, although this salt water is not suitable for all purposes.

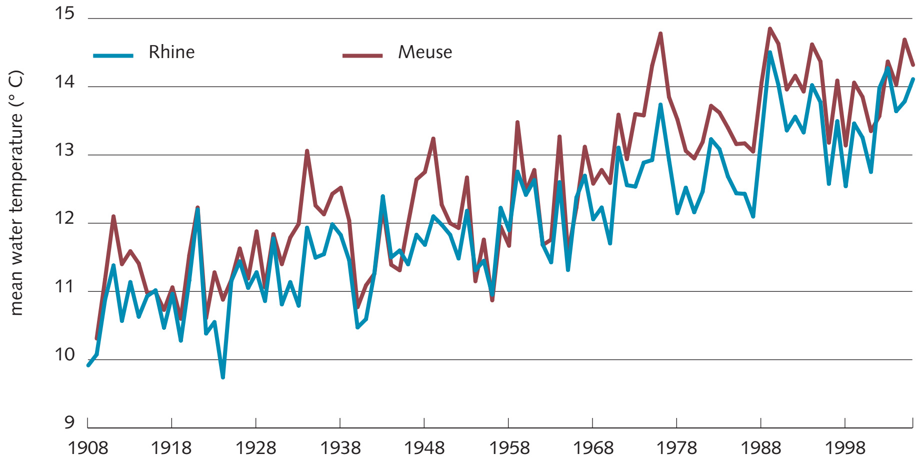
CONSEQUENCES OF LOW FLOWS

During low flows, less water is available for distribution over the country. The unique flora and fauna native to peat bogs can be irrevocably damaged by drought, and for this reason, water from the Meuse is transported in dry summers through the Zuid-Willemsvaart to the Peel to maintain the moisture content of the local peat bogs.

If the river water is at a low level, freight ships cannot transport so much cargo on those stretches of river which are not regulated by weirs. The various water users then have less water to share, which means that water shortages can occur in all types of sectors such as agriculture and market gardening, or water supply companies. And farmers and market gardeners are the very people who need extra water in periods of drought, for irrigation, sprinkling and combating the seepage of salt water. Although there is not a general shortage of water in the Rhine-Meuse estuary, there is a freshwater shortage. The river exerts less back pressure at low discharge, which



Number of days with low discharge on the Rhine (<1400 m^3/s at Lobith) an the Meuse (<130 m^3/s at Liège). Since 1900 the number of days with low discharge has hardly changed.



Rise of mean water temperature of Rhine (Lobith) and Meuse (Borgharen) from the start of the last century.

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enables the saline sea water to flow further inland. This effect is reinforced by high sea levels, in which case the river water can become so brackish that it can no longer be used for agriculture and drinking water.

The quality of the water deteriorates at low flows because pollution is less diluted, while channels and pools on floodplains and riparian zones are cut off from the river. They either become stagnant pools or dry out. Shallow stagnant water heats up easily, which provides an ideal breeding ground for poisonous cyanophyta and the botulism bacteria. If botulism occurs, poisonous substances are released that are deadly for birds and fish. Warm water contains less oxygen than cold water, and this too can cause death among the fish population. Cyanophyta and botulism can also cause health problems in humans, so the authorities advise against swimming in such cases. Fortunately, the quality of the water quickly improves as soon as the water level rises and the temperature decreases.

River water heats up quickly at low flows, mainly because low flows often coincide with warm weather. This makes the water less suitable for use as cooling water, for example by power stations. In order to prevent the water from heating up any further, its use as cooling water is restricted. The demand for electricity is also high during warm periods because air-conditioning units are often being used to their full capacity, and this can result in an electricity shortage.

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1 Discharge of cooling-water from the power-plant at Weurt (Waal). The heated water is indicated in bright blue. **2** Dessicated lake in the floodplain. **3** Houseboats in “de Strang” at Beneden Leeuwen during extremely low water levels in the Waal (2003)

COPING WITH LOW FLOWS

Weir and sluice management

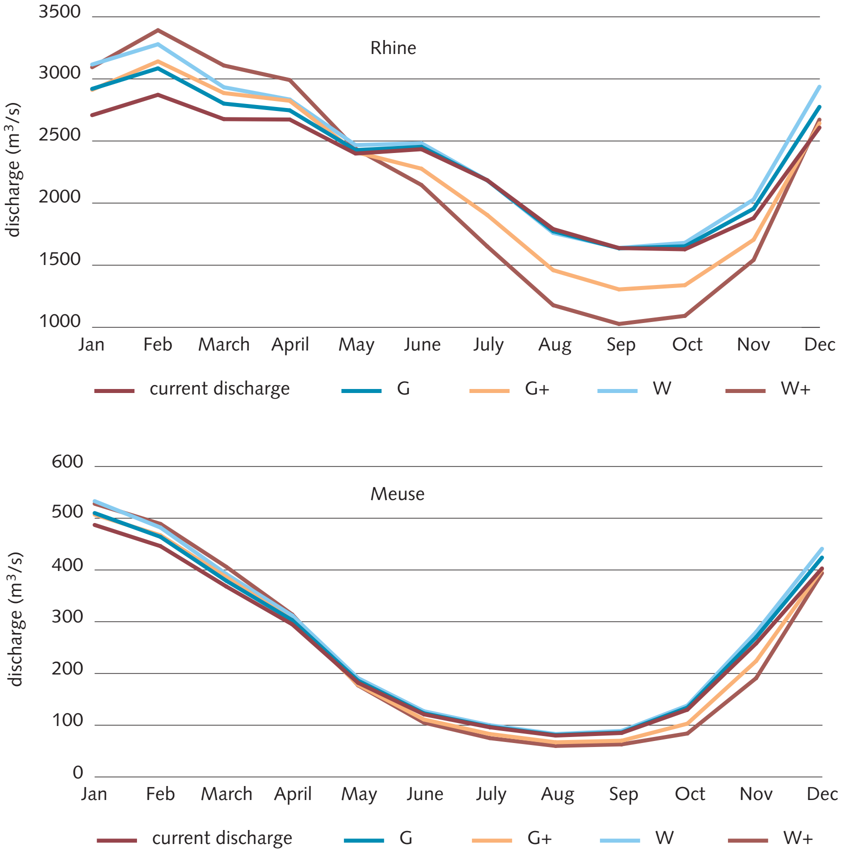
There are three weirs in the Nederrijn-Lek. The weir at Driel closes off if the discharge at Lobith drops to less than about 1,600 m^3/s. This means that a greater proportion of Rhine water subsequently flows through the Waal and the IJssel, and ships can continue to sail along these tributaries for longer. The two other weirs prevent the Nederrijn-Lek from emptying itself completely. The weirs are partially opened if the discharge is between 1,600 m^3/s and 4,000 m^3/s. If the discharge is 2,400 m^3/s or more, the weir at Driel is opened to its fullest extent, following which the weirs at Amerongen and Hagestein are opened.

There are seven weirs along the Dutch part of the Meuse. These weirs ensure that the navigable depth for shipping remains at a minimum of three metres. In 1976, the water level in the Meuse was so low that navigation was impossible, and new measures were then taken to keep the navigable depth at the right level. These measures include more efficient use of the sluices at low flows to reduce water loss when locking through. Moreover, any water that seeps out during the locking-through process is pumped back. These measures enable the navigable depth to be maintained, although passing through the sluice may take longer as a result.

The Haringvliet sluices are closed completely if the discharge at Lobith is less than 1,100 m^3/s. If the discharge is higher, the sluices open up gradually, and they are completely opened whenever the discharge is 10,000 m^3/s or more. The objective of the discharge programme is to maintain sufficient navigable depth in the Nieuwe Waterweg and at Moerdijk, and to prevent salination.

Low flows in 1976 and 2003

1976 was an extremely dry year, with a record low discharge in the Meuse and exceptionally low flows in the Rhine as well. Agriculture suffered considerable damage due to water shortages in the east of the country, cattle fodder became scarce, and forest fires broke out at a number of locations. The water became so brackish in the west of the country that it was impossible to use it for agricultural purposes, and everyone was asked to save as much drinking water as possible and to refrain from watering their gardens or washing their cars. As a matter of fact, the Displacement Series was compiled as a direct result of the 1976 water shortage. In 2003, too, the summer was a long warm dry one, and the Rhine discharge dropped to 780 m^3/s, while that in the Dutch Meuse fell to below 10 m^3/s. Although much lower discharges have occurred in both rivers in the past, the low flow level in 2003 caused considerable problems because sea water flowed a long way up the Rhine. In addition, the high water temperature resulted in botulism and problems with cooling water for power stations.



Changes of mean discharge per month at 4 different climatic scenarios for Rhine and Meuse.
In scenario G and W air-circulation patterns remain unaltered, in scenario G+ en W+ air-circulation patterns change, in scenario G en G+ global temperature rises by 1° C, in scenario W en W+ global temperature rises by 2°C (temperature in 2050 compared to 1990). *Source: KNMI.*

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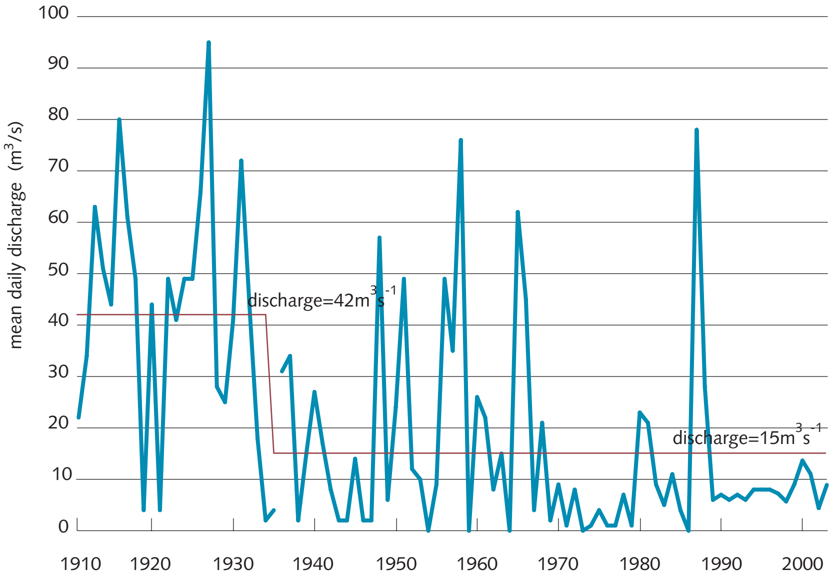

Lowest discharge per year on the river Meuse (Borgharen). Opening of the Albert canal (1935) and the Juliana canal (1939) has resulted in a decrease of low-discharge levels. In 1990 the weir at Borgharen has been automized and discharges below 10 m^3/s are mostly prevented.

Displacement series

When low flows occur, the Rijkswaterstaat Inland Waterways Information Centre assembles measurement data for 120 locations, including information on water levels, water extraction and water temperature. This data is set out on a general map of the Netherlands to show where water shortages occur. The Landelijke Coördinatiecommissie Waterverdeling (National Water Distribution Coordination Commission, LCW) then decides on the best way of distributing the water among the tributaries, lakes and canals, and whether any restrictions of water use would be necessary. When making these decisions, the LCW adheres to the national displacement series; this states which users should be given the highest priority in the event of a water shortage. The LCW draws up so-called drought reports describing the situation and the restrictions to be imposed on water use and sends these reports to approximately one thousand interested stakeholders. In addition, the water boards draw up drought reports for their own regions.

Displacement series

	Main objective	Effects
Priority 1	Safety and prevention of irrevocable damage	1. Safeguarding the stability of water-control structures 2. Preventing shrinkage in peat bogs 3. Preventing irrevocable damage to the natural environment
Priority 2	Utilities	1. Drinking-water supply 2. Electricity supply
Priority 3	Small-scale, high-quality use	• Temporary sprinkling of capital-intensive crops • Process water for industry
Priority 4	Others	• Shipping • Agriculture and market gardening • Nature (provided the damage is not irrevocable) • Industry • Recreation • Fisheries

Low discharge in the Grensmaas

There are no weirs in the Grensmaas and there is no shipping either: the water level is determined here by ‘natural’ dynamics. The relatively high flow rates and the gravel bed provide a unique environment for species native to running water. The construction of shipping canals in the Netherlands and Belgium has contributed to the frequent occurrence of low discharges whereby long stretches of the Grensmaas are left entirely high and dry. This can cause problems for fish and other river animals, since the remaining water heats up quickly and the oxygen level can drop to dangerously low levels, and there is insufficient deep water left to which large fish can retreat.

4 Low discharge on the Grensmaas

To prevent too low discharge in the Grensmaas, the Netherlands and northern Belgium ratified the Meuse Discharge Treaty in 1995, which comprises agreements on water distribution. This has since ensured the restriction of discharge into canals during periods of drought, and the surplus lockage water is pumped back into the river. The aim of this treaty is to prevent the Grensmaas discharge from falling below 10 m3/s. This minimal discharge seems to be sufficient to keep aquatic life in the Grensmaas healthy, provided that it does not occur too often.

Shipping reports

Every morning, Rijkswaterstaat measures the shallowest point at a number of locations along the river and announces these so-called 'least-fathomed depths' on the Internet. In the afternoon, Rijkswaterstaat announces the forecast for the next day. Shipmasters use this information to determine whether they are able to navigate the river and how much cargo they can carry. If the circumstances are exceptional, Rijkswaterstaat can adopt river traffic measures to prevent accidents, although this happens very seldom.

CLIMATE CHANGES

The whole world is getting warmer due to factors such as greenhouse gas emissions. Low river discharges will become more common as a result of greater water evaporation. Snow in the Alps will melt earlier on in the year, which will increase the chances of low flows in the Rhine. Climatic changes can also cause shifts in atmospheric circulation patterns, and these in turn can lead to longer periods with an east wind in north-western Europe in summer and autumn, during which very little precipitation will fall in the Rhine and Meuse catchment basin. These effects may possibly be counteracted to a certain extent by greater amounts of precipitation falling in winter; this will increase the level of sub-soil water, which will then reduce the chances of low flows in summer.

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Since it is not possible to predict exactly what all the different effects of climate change will be, the KNMI has worked out a number of scenarios in order to assess the consequences for low flows (see www.knmi.nl). It transpires that low-water problems are expected to increase the most in scenarios depicting shifts in atmospheric circulation patterns. These scenarios contain more frequent periods with extremely low discharge, and the low flow levels continue for longer periods than at present. According to the most extreme predictions, the discharge at Lobith in 2050 will only be half of what it is now during part of the summer. At the Rhine-Meuse estuary, salination is the biggest problem caused by low discharge, and this problem is expected to increase as the sea level rises.

Salination in the Rhine-Meuse estuary

Climatic changes will cause increases in sea level and more frequent low river discharge in summer, which in turn will result in the salt sea water flowing further inland. This will present problems with regard to supplies of water for drinking and regional agriculture, especially in the case of salination of the Hollandsche IJssel, the Haringvliet and the Spui. One effective way of combating salination is to shoal the river: shoaling of the Nieuwe Waterweg and the Nieuwe Maas, for instance, would prevent salination of the Hollandsche IJssel, at least for the time being. However, this measure would have an extremely adverse effect on maritime shipping going to and from the Rotterdam ports. Salination in the Haringvliet can be counteracted by discharging more water through the Haringvliet sluices, although this would also be harmful to shipping because it would cause the water level at Moerdijk to drop. On the other hand, dredging for the benefit of shipping would increase salination. This is why tackling the salination problem requires a broad-based assessment of interests. Rijkswaterstaat will be conducting an investigation into the salination of the Rhine-Meuse estuary, thereby taking the anticipated consequences of climate change into account.

5 Closed weir in the Lek at Hagestein

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HEALTHY RIVERS

Water is a valuable commodity, one which must benefit future generations as well. This is why the member states of the European Union have agreed to ensure that all waters are in good condition and that this condition is maintained. This also applies to the Rhine and the Meuse. During the next few years, the Netherlands will be working together with the other member states to devote extra effort to making the river water cleaner and restoring the indigenous flora and fauna.

WHAT DO WE MEAN BY ‘HEALTHY’?

Due to human intervention, rivers in the Netherlands have changed considerably in the course of time. By consulting old books and maps, we can deduce the natural state of the rivers, and what plants and animals lived there. Even now, there are still rivers to be found in other countries that have not been subjected to human influence to such a large degree: the Allier, for instance, gives an accurate picture of the former characteristics of the Meuse, while the Gironde is a good parallel for the Rhine-Meuse estuary and the Volga and the Loire for the Rhine tributaries. All this information from the past and from other countries can be used to deduce what constitutes a healthy and natural river.

Water in healthy rivers is clean and the flora and fauna in these rivers shows a rich diversity. Many animals and plants use the entire river for their habitat, moving freely along the banks or in the water from source to estuary. The waterside areas are flooded at regular intervals and subsequently dry out again, sand and silt are deposited and eroded away again, and drifting ice scours the whole major riverbed clean once every few years. The banks are often overgrown with riparian vegetation, while here and there sandy river dunes have been pushed up, with typical plant life and a great many insects. Secondary channels flow through the floodplains and provide spawning grounds for fish; now and again pieces of driftwood full of insects, molluscs and small shrimps can be seen floating along, while birds nest on islets situated in the main stream. The riverside areas are dotted with pools and shallow lakes where water plants flourish and young fish can safely reach maturity. When these waters come into contact with the main channel, the plants and fish they contain can spread all along the entire river. Floods trigger off an invasion of benthic animals upstream. As soon as the water level drops, these newcomers seek a suitable habitat where they can form a new population.

Heavily modified Rhine and Meuse

The Rhine and Meuse in the Netherlands can no longer be classified as healthy rivers. Dyke construction has made the floodplain much smaller; and a large part of it has been cultivated, mainly for agricultural use. A bare 19% [checken] still consists of more or less natural habitats. Due to groyne construction and dredging, the main channel has become considerably deeper and a large number of banks have been covered with riprap, which has largely severed contact between the rivers and their banks. Secondary channels no longer originate naturally, and there are very few natural banks and riparian vegetation left. Steep overhanging banks and sandbanks no longer exist, and the link between the sea and the spawning grounds upstream has been broken as a result of weir and dam construction. Due to the disappearance of these natural habitats and links, typical riverine species such as the brown galingale, the black poplar, the little ringed plover, salmon and river lamprey only occur very rarely nowadays. Their place has been taken by commoner species that are less demanding with regard to habitat quality.

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Due to inferior water quality, many species disappeared, especially round about the 1950s, although the quality of the Rhine and Meuse water has since improved. This improvement was achieved using all kinds of drastic measures such as decontamination of large-scale industrial discharge, introducing phosphate-free detergents, constructing purification plants for waste water, and banning a number of extremely toxic substances. The Pollution of Surface Waters Act (1969) has also made a considerable contribution to cleaner water. However, the quality of the river water has not improved any further since the 1990s: this is primarily apparent from the copper and zinc concentrations and the presence of nutrients such as phosphorus and nitrogen. About 70% of the pollution of the Rhine and Meuse water originates from abroad; in the Netherlands, agriculture is one of the major sources of pollution. The quality of the water is still insufficient for delicate species such as certain benthic animals; in fact, on occasion it is not even suitable for use in preparing drinking water.

Many pollutants in the water adhere to small silt particles and are thus able to accumulate in the layers of silt deposits, which means that the quality of the riverbed and the bottom of floodplains at some locations is frankly appalling. Although the upper layer is cleaner thanks to improved water quality, pollution is still present underneath, and pollutants can travel back into the water via the riverbed. Moreover, worms and other invertebrate inhabitants of the riverbed absorb pollutants into their bodies because they eat silt, so other animals that live on these invertebrates subsequently absorb the pollutants in turn. In this way, toxic substances accumulate in fish, birds and mammals, and this can have detrimental effects on their hormone regulation. The major substances that cause this kind of problem are heavy metals, PAHs and PCBs.

	domestic	**overseas**	**main source**
nitrogen (=N-total)	26	74	agriculture
phosphate (=P-total)	33	67	agriculture
zinc	21	79	road traffic (worn tyres)
copper	21	79	road traffic (corroded brake-linings)
nickel	0	100	industry
fluoranthene (PAK)	99.7	0.3	ship's coatings
benzopyrene (PAK)	27	73	atmospheric deposits

Origin of a number of substances that regularly exceed the prescribed norms in rivers. Cadmium exceeds the norm only where the Meuse enters the Netherlands. Inland impact based on calculations from the emissions register (http://www.emissieregistratie.nl) and foreign impact based on actual measurements at Lobith and Eijsden.

RIVER RECOVERY

The Dutch authorities are currently devising a network of natural areas in the Netherlands known as the National Ecological Network (EHS). The EHS will eventually occupy a total of 100,000 hectares in the riverside area. A large part of this area is

1 Volga (Russia) **2** Allier (France) **3** Danube (Hungary) **4** Sewage purification plant at Boxtel along the Dommel. **5** Measurements of oxygen and flow rate.

still being used for agriculture at the present moment. If the owner of one of these agricultural areas wants to sell his land, the government has the right to purchase it and lay it out afresh. The acquistion of new natural areas is behind of scedule. Main causes are financial deficits and long procedures. The Netherlands has made agreements with the countries adjoining the Rhine that migratory fish such as salmon must be able to swim freely from the sea to the spawning grounds upstream, and to this end, facilities will be necessary at weirs and other similar obstructions.

The European Union is determining water policy to an increasing extent by establishing directives with which all member states have to comply. The objective of the Birds Directive and the Habitats Directive is to preserve and develop natural habitats and indigenous species. These protected areas will eventually form one vast European network of wildlife areas known as Natura 2000. The Dutch government has already allocated large parts of the floodplains and riparian zones bordering the major rivers as part of Natura 2000, due in part to such factors as the existence of softwood riparian vegetation, species of pioneer vegetation on mud banks, river valley grasslands, wintering geese and ducks, and endangered summer birds such as the spotted crake, the cormorant and the corncrake. More information on these directives can be found on the Ministry of Agriculture, Nature and Food Quality website (www.minlnv.nl).

The EU Water Framework Directive states that all water systems must be restored to the cleanest and most natural condition possible. However, this is not always possible if a water system has been considerably altered due to human intervention: the Nederrijn-Lek and the Meuse, for example, are both rivers that have been canalised. In order to restore them to their original state with river dunes and natural levees, the weirs would have to be removed, in which case they would no longer be navigable for shipping. Although this means that a natural condition is not feasible for these rivers, it does give some indication of the right way to go about things. Each country sets attainable and affordable objectives for its own waters, and the measures required are laid down in river basin management plans. Countries situated within a river basin consult with one another to ensure that the objectives and subsequent measures all harmonise. These objectives will have to be achieved by 2015, although postponement until 2027 at the latest may be granted under certain conditions. For more information, please see www.kaderrichtlijnwater.nl.

Getting the measure of things
Rijkswaterstaat constantly monitors the quality of the water at the borders: at the Bimmen-Lobith bi-national measuring station for the Rhine, and at Eijsden for the Meuse. All changes are immediately recorded at these stations, which enables Rijkswaterstaat to warn water boards and other river-water users in good time if any serious pollution is detected. Collaboration with other countries is of especial

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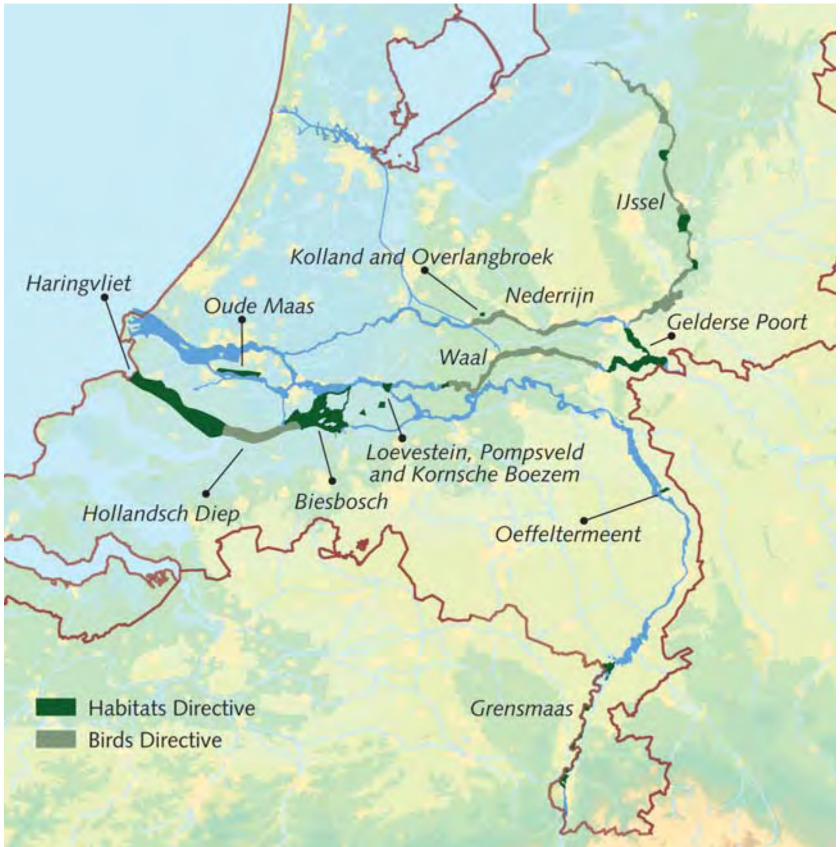
importance to the Netherlands, since countries situated upstream often spot any pollution earlier on and can then warn the other countries downstream. To this end, the International Commission for the Protection of the Rhine has set up the International Warning and Alarm Plan for the Rhine, in which seven alert stations in Switzerland, France, Germany and the Netherlands cooperate on reports on acute water-quality problems in the Rhine (www.iksr.de). A similar alert system also exists for the Meuse (www.meuse-maas.be).

Besides its watchdogs at the borders, Rijkswaterstaat has measuring stations at other locations along the rivers, and these measurements show which substances cause the biggest problems. According to the Water Framework Directive's international norms, rivers in the Netherlands contain too many heavy metals (cadmium, lead and nickel), while concentrations of tributyltin (a substance found in marine paint), diuron (a pesticide) and PAHs are too high as well. Moreover, the amounts of fertiliser, copper and PCBs in the rivers also exceed the Dutch standards. And that is not all: it is exceedingly probable that the water also contains substances which are unknown and therefore cannot be measured, while new substances regularly make their appearance. No standards have yet been established for these substances because the effects are unknown.

"The German and Dutch measuring stations used to be opposite one another, one on each side of the Rhine. If we measured any pollution, we rang the Germans to ask if they had also spotted it. But the stations were amalgamated in 2001 and we now work together to measure the quality of the water. If we find high concentrations of pesticides, for instance, the Germans immediately work out where exactly in Germany these substances entered the water, while we Dutch advise our water boards to stop collecting water for a while. Sharing the tasks like this works really well.

It's a continuous working plant here; all the measurements are carried out at weekends too. We analyse water samples in our lab. We've found pretty high levels of MTBE at regular intervals during the past few years; this is a substance used as a lead substitute in petrol and mainly comes from the Ruhr area. And we also come across excessive concentrations of diglyme, benzene and xylene fairly frequently. We sometimes find too many pesticides like isoproturon in the Rhine water in spring. You can see the day-to-day water quality on www.aqualarm.nl.

It's quite possible that all these substances are not harmful when taken separately, although they may well be so in combination. It's also possible that unknown substances are present in harmful concentrations. That's why we've installed our biological surveillance system: a cylinder containing water fleas is filled with fresh Rhine



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6 Both wintering and breeding geese are protected in the riverine area by the European Birds Directive. **7** River pondweed is a characteristic macrophyte species for healthy rivers. **8** Natura 2000 areas in the Netherlands.

water at regular intervals, and a camera monitors the water fleas' movements. As soon as the camera registers any aberrant movements, like for instance if the fleas start swimming in circles at a fast rate or if they're all lying at the bottom of the container, one of us is automatically alerted by mobile phone. This enables us to intervene quickly."

Gerrie Pieper, co-worker at Bimmen-Lobith measuring station

MEASURES

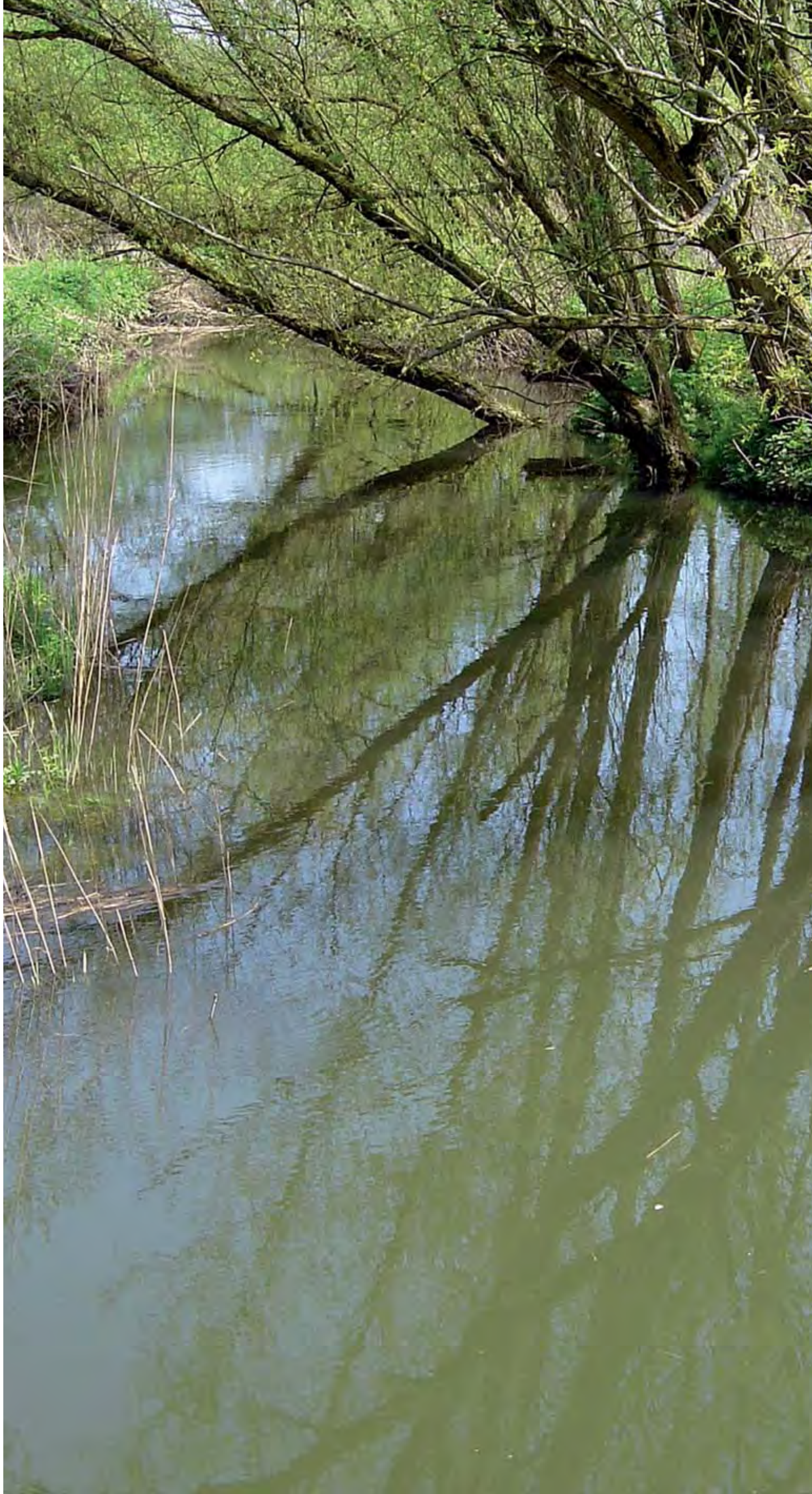
A great deal of hard work will have to be put in during the next few years to attain the objectives laid down in the Water Framework Directive, the Birds and Habitats Directives and the National Ecological Network. Fortunately, the Netherlands has already acquired a great deal of experience during the past decades, which is a source of inspiration for the future.

Clean water

A considerable proportion of the river pollution originates in other countries, and for this reason, the Netherlands will be urging Belgium, France and Germany to reduce their discharges. Belgium, for instance, still discharges a great deal of unpurified household waste water into the Meuse. The European Water Framework Directive gives the Netherlands a stronger position in its negotiations with other countries than in the past: all countries will have to comply with international norms for the most dangerous substances, and are legally obliged to work together to tackle cross-border problems.

Other measures are also conceivable in the Netherlands. Pollutants flow into the major rivers via regional waters such as ditches, tributaries and smaller canals. Large quantities of fertilisers and pesticides were used for agricultural purposes in the past, and some of these can seep into the water during heavy showers. The Netherlands may have to introduce more stringent requirements concerning the use of fertilisers and pesticides, and an additional measure is to install buffer zones along the borders of agricultural areas to help reduce the amounts of fertiliser and pesticides that enter the water. Sewage purification plants can extract even more pollutants from the water by adding on an extra process. This so-called fourth step is able to remove more fertiliser from the water, as well as organic micro-pollutants such as pesticides, hormone-disruptive substances and medicines. It is not yet certain whether the costs of this expensive after-processing actually do counterbalance its effects. During the next few years, the water-management institutions (Rijkswaterstaat, provincial authorities, water boards and municipalities) will be joining forces to draw up a catchment basin management plan containing the necessary measures to be taken.

If we make the water cleaner, it is just as important to make the channel bed cleaner too. This will prevent more pollutants from entering the water via the channel bed. Most of the silt stays at the bottom of the Rhine-Meuse estuary, which means



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that the problem of polluted (channel) beds is the most severe at this location. Decontamination can often be combined with nature development; one example of this is Klein Profijt on the Oude Maas, where 6 hectares of new wetlands have been created by excavating the polluted bed and laying out the area afresh. If lowering the bed is not desirable, clean soil can be replaced on the bed after removing the polluted soil. Another option would be to cover up the polluted river bed so that the pollution cannot come into contact with the water: this has already been done at a number of locations including the Hollandsche IJssel.

Hollandsche IJssel cleaner and more beautiful

The Hollandsche IJssel was once a magnificent fresh-water tidal river. However, a great deal of its beauty has been lost during the past hundred years, and its banks are now heavily polluted. In 1998, water boards, Ministries, provincial and municipal authorities combined to restore the Hollandsche IJssel. One of the first steps taken was to decontaminate one of the banks at Moordrecht in 2000 and to lay it out as a natural area. Rijkswaterstaat excavated the area and used clean materials in the restoration process. The river has also been provided with a nature-friendly riverbank and a secondary channel. And in 2001, the contaminated riverbed at Nieuwerkerk was covered up with clean sand. This created a dried-up mudflat with reed colonies on the higher parts. Nature can now develop again at both these locations in a way characteristic of fresh-water tidal rivers. It has transpired from the first measurements taken that chemical pollution at these two locations has considerably decreased, while benthic animals quickly settled there immediately after restoration, attracting new fresh-water tidal species in turn. This shows that a stable ecosystem comprising numerous species is developing. Recovery has taken place more rapidly at Moordrecht than at Nieuwerkerk, probably because the silty bed at Moordrecht provides more nutrients for riverbed life. For more information on the Hollandsche IJssel project, please surf to www.schonermooier.nl.

Linking sources to estuaries

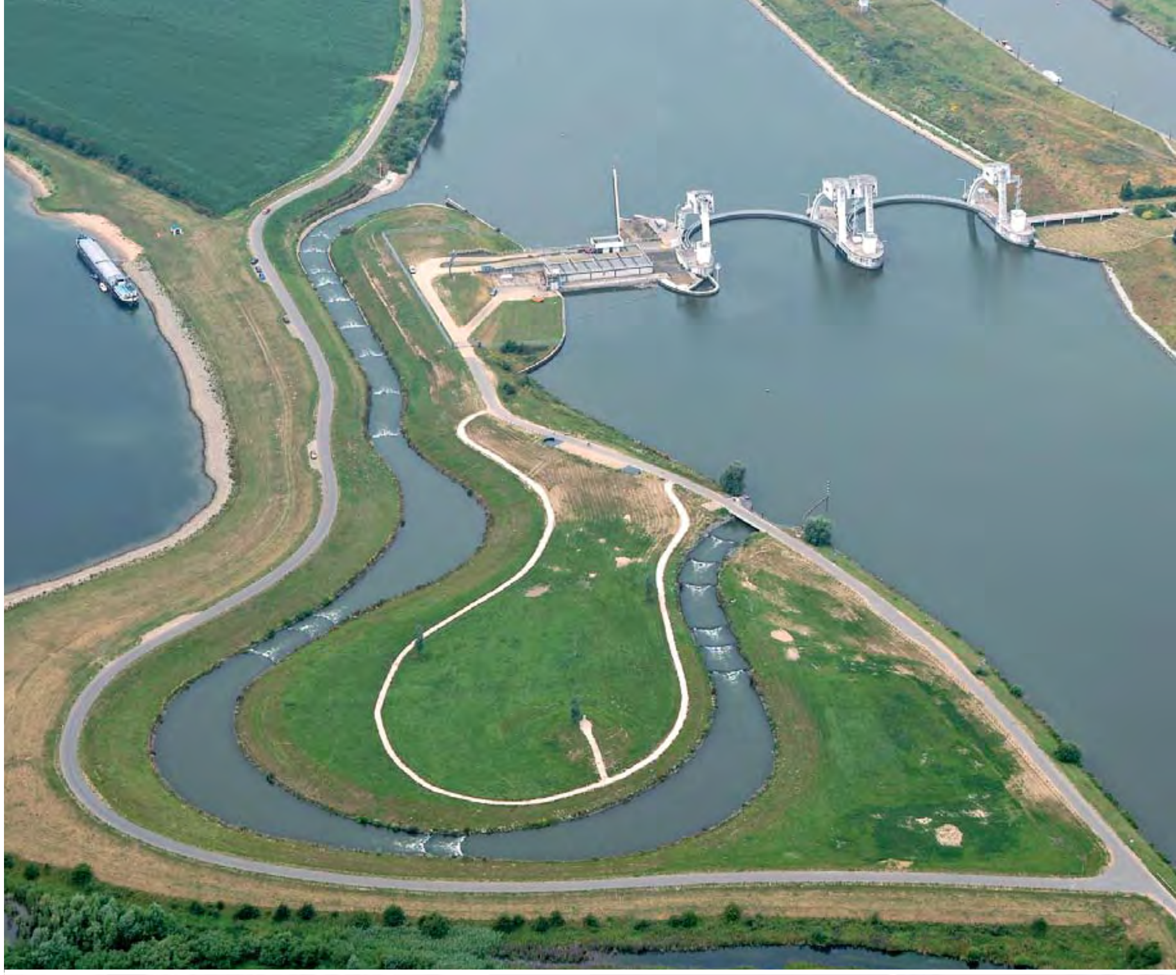
For the ecological recovery of the rivers to be successful, it is important that animal and plant species are able to move unimpeded in and along the river from its source to its estuary. Migratory fish sometimes have to swim hundreds of kilometres up-river in order to reach spawning grounds, and the presence of impregnable barriers prevents them from doing so. For this reason, countries in the Rhine and Maas catchment basin have agreed to construct fish ladders on all weirs on Rhine and Meuse. Nine

9 Klein Profijt along the Oude Maas **10** Lower reach of the Geul (tributary of the Meuse).

out of the ten weirs along the Dutch part of the Rhine and the Meuse have meanwhile been provided with a fishway, and the fish ladder at Borgharen will be finished at the end of 2007. In 2003, the very first salmon was able to swim along the river from the sea right up to Belgium on its way to spawning grounds in the Ardennes. And even more benefits can be reaped in the Netherlands by restoring the links between the major rivers and the smaller adjoining tributaries. Rijkswaterstaat and the water boards have agreed to restore 64 rivulet estuaries along the Meuse. The water boards have already made a great many obstacles in the side tributaries passable so that the entire catchment basin will eventually be accessible again.

The last barrier for migratory fish in the Netherlands is the connection between the rivers and the sea. Although the Nieuwe Waterweg is admittedly an open connection, it turns out that this busy shipping route is not very attractive for fish. The route through the Haringvliet is a great deal quieter, and for this reason, as from 2008, Rijkswaterstaat will be setting the Haringvliet dam sluices ajar at high tide so that fish can swim to and from the sea. This means that the water near the Haringvliet dam will become more salty, which is good for characteristic species that dwell in brackish water. However, four inlet points for agricultural and drinking water will have to be put in position before the sluices can be set ajar. Rijkswaterstaat and its partners may well decide to open up the sluices still further in the future in order to allow characteristic tidal species to return to the Haringvliet, the Hollandsch Diep and the Biesbosch.

Not only fish, but mammals, birds and plants must also be able to move along the rivers, and to help them do so, the larger natural areas must be connected up with one another by corridors along the river. This will enable species to colonise new natural areas, and is also important for plant seed distribution. A further consequence of this is that populations in individual areas will be less vulnerable to extinction. Nature-friendly riverbanks have already been constructed at numerous locations along the rivers during the past 20 years, particularly the Rhine tributaries and the Rhine-Meuse estuary. During the coming years, 70% of the banks lining the Meuse will also be laid out in



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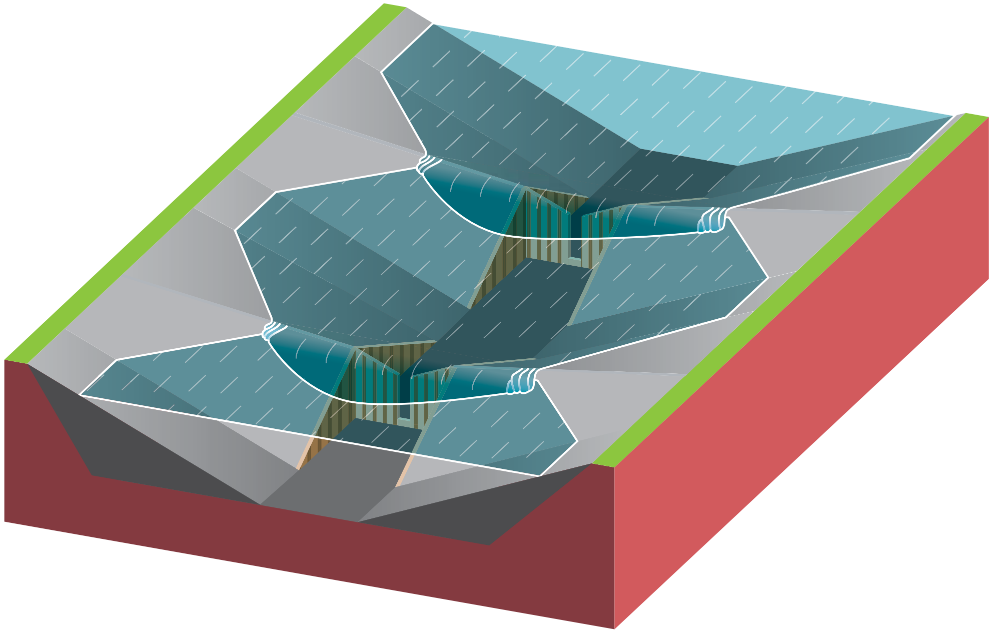
a nature-friendly manner. Natural erosion and sedimentation processes will once more have a free rein, provided that there is enough space and other processes permit this, and to this end, rock-fill on banks will be removed. The nature-friendly riverbanks can be protected by bank reinforcements at locations where less dynamics are desired.

Besides narrow corridors along the rivers, the higher animal species in particular require large-scale wildlife areas adjoining one another. The major natural cores in the Netherlands are the Gelderse Poort, the Grensmaas and the Biesbosch. Smaller stepping-stones the size of a floodplain serve to reinforce the network.

Fishways

Salmon migrating from the sea to the spawning grounds in the Ardennes can bypass almost all weirs through fishways. But these fishways must be functional: fish have to be able to find them, as well as to swim through without any problems. If fish encounter a barrier, they start looking for a place with swiftly-flowing water. This is why sufficient water has to flow through the fishways in order to lure the fish there. The entrances must be situated at a location where the running water is not disrupted by other currents arising as a result of e.g. weirs or power stations. Weir managers should take this into account during migration periods. The ease with which fish can negotiate fishways mainly depends on the flow rate and fall of the water. Variations in flow rate ensure that strong swimmers as well as the less strong swimmers can swim against the current. The pool-type fish ladder has turned out a real success, with its V-shaped sills and deeper groove in the middle enabling benthic fish and smaller fish to swim up the ladder too. From a survey conducted by Rijkswaterstaat into what types of fish make use of these fishways, it transpires that as many as 33 species use the fishways in the Nederrijn-Lek, from



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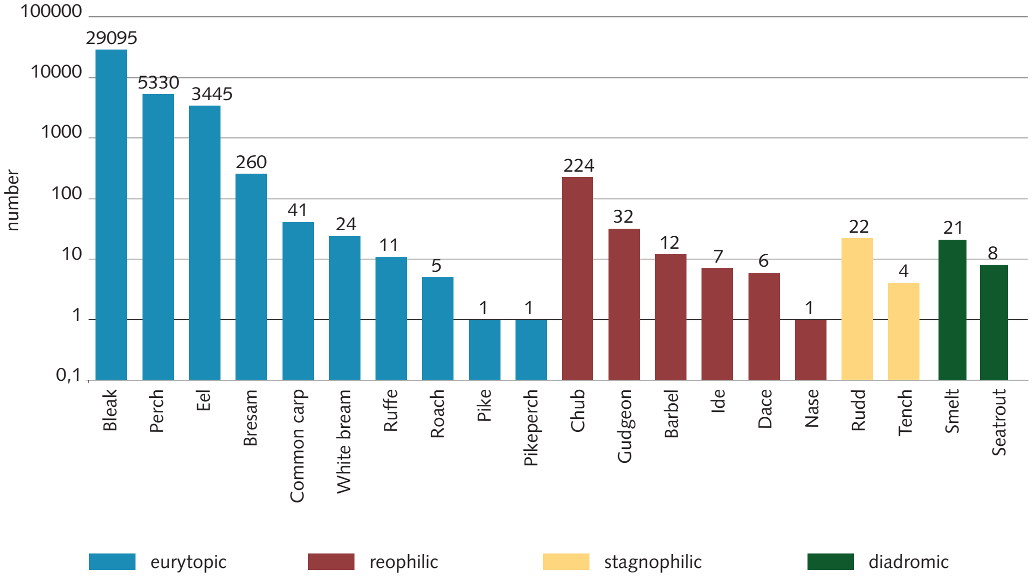


Species composition (x-axis) and catches (y-axis, logarithmic scale) in the fishways at the weirs of Belfeld and Lith from April to June 1993. From: Lanters R.L.P. ,1994. Onderzoek aan vispassages. Monitoring van de visoptrek. In: Lezingen en posterpresentaties van de Studiedag Vismigratie 15 december 1993. Ed. A.J.P. Raat. Organisatie ter Verbetering van de Binnenvisserij, Nieuwegein, 201-211 p.

11 Fishway near Amerongen **12** Cought passing throug the fishway (clockwise): River lamprey, Perch, Roach, Seatrout. **13** V-shaped pool-and-weir type fishway with vertical slot.

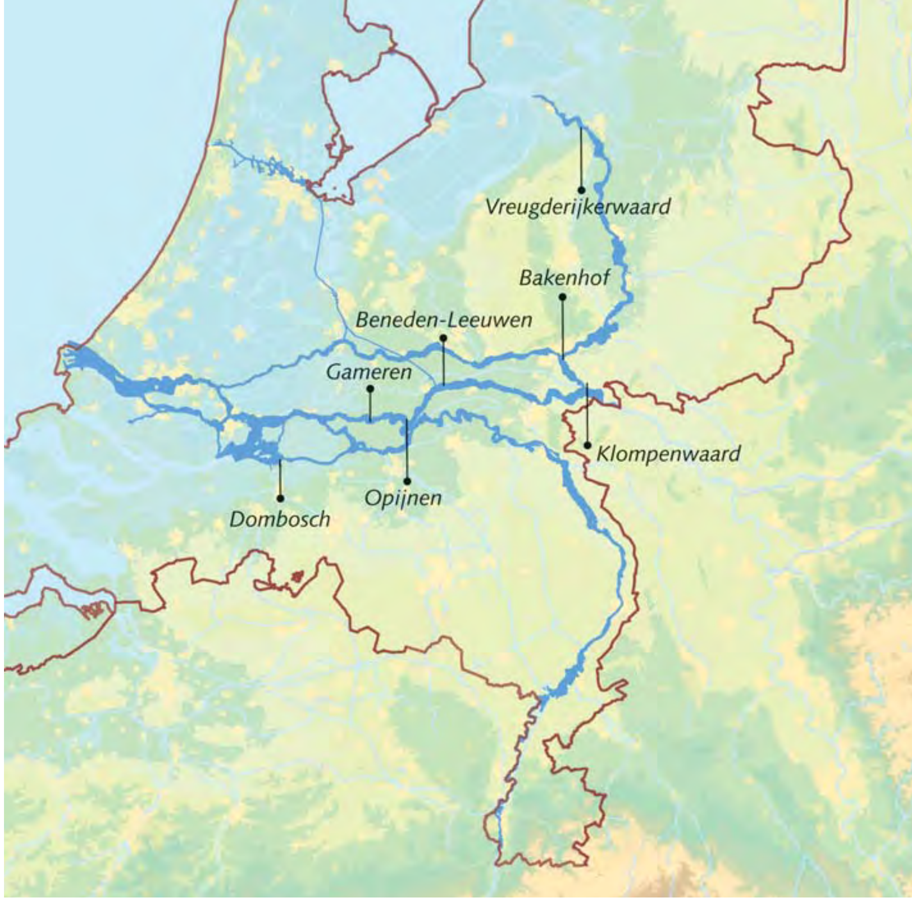
the huge pike to the tiny stickleback. The fish that scores the best is the bleak, a fairly common species that migrates upstream in large schools during the spring spawning season. Large numbers of river lampreys also use the fishways, although this takes place in autumn.

Linking the major and minor riverbeds

The floodplains are often silted up to the extent that they are only flooded at extremely high discharges. This has put a stop to the exchanges of water between the main channel and the major riverbed, and species such as the marsh sandpiper, the Brown Argus butterfly and the northern vole have decreased considerably in number. Habitats for these species can be restored by removing the summer dykes and lowering the floodplains. The original natural relief will be restored to the surface merely by removing the topmost layer of clay; this clay can be sold in order to cover the costs of the layout. It has transpired from the first flood-plain-lowering projects that rare pioneer species are the first to develop on the new low-lying sandy substratum: these species include the spreading cinquefoil, the red bartsia and the mudwort, while brushwood and riparian vegetation develop at a later stage, and willows germinate along the lowest parts immediately after the area has been laid out afresh.

Species that live in shallow running water also have a hard time, since the deep main channel is no longer an attractive habitat for such species. However, this habitat can be substituted by digging secondary channels in the floodplains and riparian zones and connecting them to the main channel at both ends. Another possibility would be to link up existing pools in the floodplain with the main channel upstream and downstream. The first projects carried out show that characteristic benthic animals soon return to settle in the secondary channels. One example of this is the larvae of the yellow-legged clubtail, a species of dragonfly that had become extinct in the Netherlands and that has returned in large numbers to secondary channels along the Waal during the past years; it has meanwhile been observed at locations along the Meuse, the Merwedes and the Biesbosch as well.

Lowering the floodplains and digging secondary channels not only benefits wildlife, but it also helps protect against flooding. These measures widen the major riverbed, and more water can flow through as a result. During the coming years, the recovery of this natural environment will be primarily achieved by the implementation of the 'Room for the River' Spatial Planning Key Decision and the Maaswerken Project. The Grensmaas project, which forms part of the Maaswerken Project, will create 1,200 hectares of new natural environment. This area will be doubled if the plans for the northern Belgian part of the Grensmaas are implemented. Nature and safety will benefit equally by widening the riverbed; this widening will be effected by gravel extraction.



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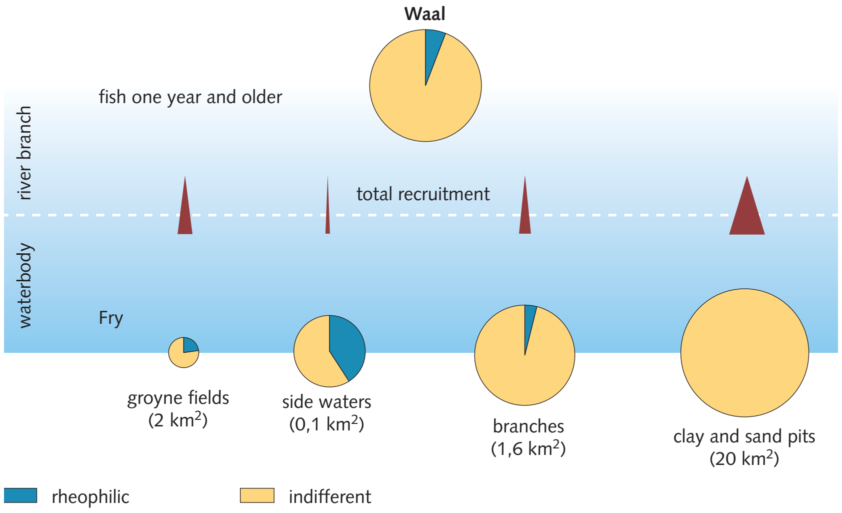

The importance of side-waters and groyne fields for fish. The upper circle indicates the composition of the fish-community in the river (Waal). Main determinant is the reproductive rate in the several floodplain waters and groyne fields. The size of the circle indicates fish density.
(After: Grift, R.E., 2001. How fish benefit from floodplain restoration along the lower River Rhine. Proefschrift Wageningen Universiteit.

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Polluted soil may be stirred up during the excavation of floodplains and the construction of secondary channels. This soil can often be used for other purposes in the area. If this is not possible, the polluted soil will have to be transported to special storage depots such as the Slufter on the Maasvlakte, Keteloog in the Ketelmeer lake, or the new silt depot in the Hollandsch Diep. This may well make these measures extremely expensive.

Meers Pilot Project

In 1999, a pilot project was started up at Meers on the Grensmaas, in which the river-valley plain has been extensively widened along an area comprising 36 hectares, by the excavation of gravel. This has resulted in a dynamic landscape with gravel ridges, spectacular erosion pools, flood channels and islets with riparian vegetation. Measurements have shown that the indigenous flora and fauna returned within a time span of five years.

One remarkable fact is the speedy return of a number of river-valley plants and species of pioneer vegetation to the dynamic gravel ridges. Although both types of species are characteristic of riverside areas, they rarely occur due to the lack of this kind of dynamic location: transport of plant seed along with the river water seems to be a crucial factor for the return of plants. Butterflies such as the Brown Argus and the Queen of Spain Fritillary also benefit from the dynamic environment, and Meers is now one of the few places in the Netherlands where the swallowtail is able to reproduce. The rare marsh sandpiper breeds on the gravel banks, while sand martins and kingfishers nest in the steep eroded walls.

Clumps of willows will soon grow without any intervention in the less dynamic parts of the area. Large herbivores were turned out to graze at Meers immediately after renovation in order to prevent the willows from impounding water discharge too much, and to maintain a sufficient habitat for pioneer species. Nightingales can be heard on summer evenings in less dynamic parts of the area, and the first traces of beavers have been observed.

Gamerensche Waard

Three secondary channels were constructed on former agricultural land in the Gamerensche Waard on the Waal at Zaltbommel between 1995 and 1999. These three channels vary in length (500-2000 metres), width (5-50 metres), depth (0-20 metres) and discharge (1-3% of the river discharge), and constitute the biggest secondary-channel system in the Dutch rivers. Room for erosion and sedimentation has been created in the channels, and measurements taken at the Gamerensche Waard show that the secondary channels do not pose any extra risks regarding safety or shipping.

14 Secondary channels branched on two sides along the Rhine branches. **15** Konik horses keep the vegetation structure open through grazing. **16** Pilot project Meers: a dynamic landscape with many characteristic species.

As in other nature development areas on the Waal, vegetation native to muddy banks has developed satisfactorily along the secondary channels. These species do not stand a chance along the main stream. A great many more species of benthic animals were observed soon after the channels were constructed. Benthic animals are most frequently found in places with silt and vegetation in shallow slow-flowing water with little erosion or sedimentation. The channels also serve as a nursery for fish native to running water such as barbel, chub, nase, orfe and river lamprey, and the young fish will migrate to the main channel after reaching maturity. However, many more secondary channels are required in order to ensure a quantifiable recovery of the fish population in the main channel; at the present moment, secondary channels make up only 0,1% of the Waal's surface area.

Flood protection and nature

More new nature will arise along the major rivers. We cannot predict in detail what this nature will look like, and it is bound to change during the course of time anyway. Basically, more natural vegetation such as brushwood or riparian vegetation will develop on former farm land. Since these types of vegetation are 'rougher' than smooth flat grassland, this may result in a rise in the water levels. This is not a problem in most areas, but should any such problems arise, supplementary measures will have to be taken. For example, large herbivores can help natural areas to become more open in structure. The first experiments with nature development projects show that grazing should start during the implementation of the layout measures. Cattle and horses can then start grazing on the willows right from the beginning, since these willows shoot up very quickly on the bare, damp soil. If this grazing is not started at the beginning, scrub and thickets can develop quickly, which is almost impossible for the grazing animals to deal with.

The most natural solution would be for the river itself to maintain the balance between space and water. In a natural situation, processes such as erosion and sedimentation ensure that the vegetation is swept away at regular intervals and that development can start up again from the pioneer stage. This not only provides room for water, but also for useful pioneer species that have become increasingly uncommon along the rivers.

But these processes are only possible on a limited scale, since management and layout measures may be necessary as a substitute for large-scale riverine dynamics in order to be able to guarantee continuation of safe discharge. Flood-plain lowering or channel constructions are just as likely to put development back at the pioneer stage. Local riverine dynamics may be sufficiently strong to maintain pioneer situations for longer. If it is desirable to maintain valuable flora and fauna within a given area, essential river-widening action can often be carried out in another area. The effect of decreasing the water level is often spread out over a number of kilometres. Rijkswaterstaat informs the site managers of the margins within which natural processes may be allowed to proceed; this type of management is known as cyclic management (www.cyclischbeheer.nl).

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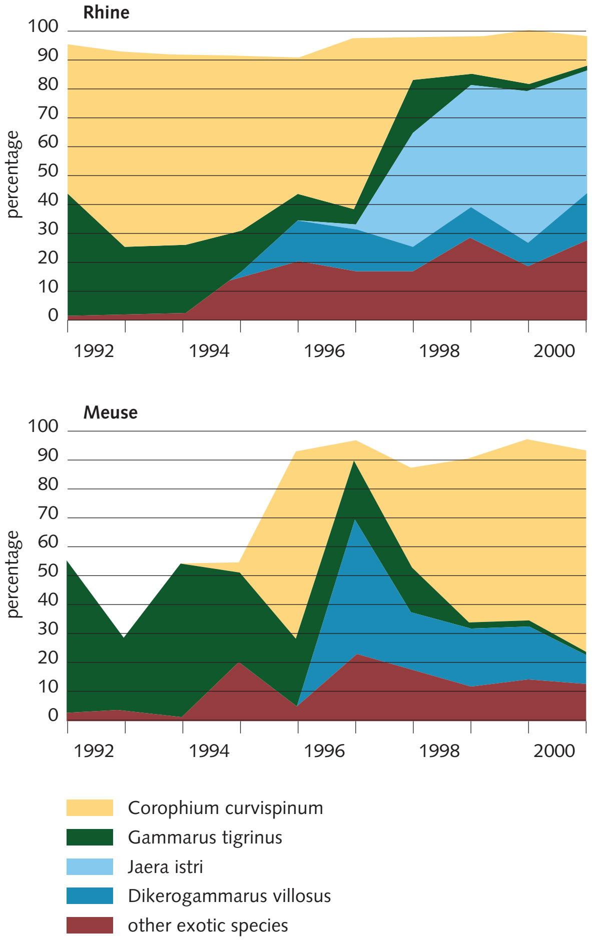

Relative abundance of exotic species in macro-evertebrate community on artificial subtrate in Rhine (Lobith) and Meuse (Grave).

New river dwellers

An increasing number of exotic species are found in riverside areas: these plant and animal species are alien to Dutch rivers, such as the mud shrimp and the zebra mussel. Problems might well arise if, due to a lack of natural enemies, these alien populations show explosive growth and supersede the indigenous fauna. Measurements carried out in Rhine and Meuse indicate that this is actually happening. About 99% of the species that live on hard substratum now consists of exotic species. Alien species of fish in our rivers include the tubenose goby and the white-eye bream, although these do not yet dominate indigenous fish to a great extent.

Exotic aliens have migrated to the Netherlands via an increasing number of links between water systems that were originally separate from one another. One example of this is the Main-Danube Canal, which has linked the Rhine and Danube catchment basins since 1992. Moreover, exotic aliens often hitch a ride on ships that sail all over the world, for example in ballast water, and aquarium owners dump exotic fish in ditches or flush them down the toilet. Although most exotic species are unable to withstand frost, they are often well able to survive in the neighbourhood of cooling-water discharge outlets. And, since the water is getting increasingly warmer as a result of climate change, they may well be found everywhere in Dutch rivers in the future. The advent of exotic aliens is difficult to halt: prevention is better than cure. They can be prevented from becoming the dominant life form by ensuring sufficiently-varied habitats.

Onze Groote Rivieren

“Now that our rivers are changing so much, and new banks and new dykes are being constructed at so many places, it is most agreeable and entertaining for nature lovers to see how Nature herself once more embellishes the fruits of human labours – which are invariably new and simple – in the course of time.”

Source: ‘Onze groote rivieren’ by Dr Jac. P. Thijsse (1938).

17 In spite of their safe house, caddishfly are sensitive to poor water quality. **18** Spined loach is protected by the European Habitats Directive. **19** The Chinese mitten crab is the most abundant species in fishways along the Dutch rivers: at occasions tens of thousands of crabs are caught during monitoring of the fishways. **20** Little Ringed Plover is a pioneer species that breeds on bare ground, free of vegetation. **21** Along the dynamic parts of the Rhine branches, Bidens radiate can be found on sandy and silty banks, along floodplain lakes and secondary channels.

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NEW TRENDS IN RIVER MANAGEMENT

Water in the Netherlands needs more room, and for this reason, water management is overlapping more and more with spatial planning. This has far-reaching effects on the water managers' work. Space is limited and needs to be used for many purposes, and citizens, businesses, stakeholders and the authorities will have to join forces in devising plans.

SOCIETY AT THE CENTRE

Citizens want less interference from the authorities. They want to feel they are getting their money's worth from what they pay in taxes, and they want more of a say in how their tax money is spent. Rijkswaterstaat is anticipating this by radically changing its way of working. Right from the start of a new project, it must be clear what politicians want to achieve, and how much scope there is for the local people and other stakeholders in the area to have their say. If the final result has not been clearly defined, the local people can still exert a great deal of influence on the actual execution of the project, and can be encouraged to participate in discussion and maybe even help to decide the final outcome. Sometimes the mandate given to Rijkswaterstaat is very specific and leaves no room for manoeuvre. In such cases, it is up to Rijkswaterstaat to provide the public with the necessary information, and to do this correctly, comprehensively and in plain language.

Getting the local people involved often brings surprising solutions. For example, residents and companies in the Overdiepse Polder came up with a suggestion of their own for renovating their district along the Bergsche Maas after they heard that the authorities wanted to use this polder to give more space to the river. The local people want to keep on living and working in the area, and to this end, they propose that their houses and businesses be built on raised areas along the dyke. In Lent, too, the local residents decided to take control of their situation by proposing an alternative plan for the repositioning of the dykes near Nijmegen. In the end, the government decided to go through with its plans because the alternative does not leave enough room for the high river discharges anticipated in the future.

Kitchen-table discussions in the Noordwaard

The depolderisation of the Noordwaard can lead to a considerable reduction of flood levels in the region. Should this plan be carried out, the river water will flow through the polder through flood channels during flood events. This will considerably alter the living and working environment of the 50 households and 25 farms in the Noordwaard. Rijkswaterstaat discussed a draft version of the plan with each household and farm individually. These 'kitchen-table discussions' made clear what the effects of this operation will be for each person involved. It transpired that most of the objections could be resolved with relatively small alterations to the plan. For example, a road which crossed right through a horse pasture in the original plan was diverted so that it now goes around the edge of the pasture. The current plan also includes a low retaining wall along one of the channels to stop a pretty local pond from being regularly washed away. This individual approach to objections means that the support base for the project has grown significantly.

At present, water management is covered by a great deal of different legislation, which makes it difficult for both water managers and users to keep abreast of all the regulations. Anyone wanting to carry out an activity in the river area may find that

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he needs to apply for as many as six different permits from various authorities. This is why a new Water Act will be introduced which will replace eight existing laws. The main objective of the Water Act is the proper and sustainable functioning of water systems, and in the future, there will be one sole water permit for all activities in the water system and one sole contact point for coordination with any other permits required; the new Act is expected to take effect in 2008.

"The gravel along the Meuse in central Limburg is an important product for the building trade. Gravel excavation in the past has led to the creation of a large area of lakes, which together are about one-third of the size of the Frisian lakes. These lakes don't fit in with our Limburg countryside. When new plans emerged in the early 1990s to begin large-scale gravel excavation in Born, the Vereniging Federatief Verband tegen Ontgrindingen in Born was established. Various groups have affiliated themselves to the association, such as neighbourhood groups, the IVN environmental education society's local branch IVN Land van Swentibold, and the local historical society 'Bicht'. This means that the association represents a sizeable portion of the population.

In January 1994, the nature development plan for the Grensmaas area, 'Green for Gravel', was submitted: in exchange for shallow gravel excavation, nature would return to the area. This was a good plan. However, in the following years the Meuse burst its minor bed on two occasions. Although this caused a great deal of inconvenience, it did not result in life-threatening situations such as those occurring along the dyked rivers. Even so, this led to a lot of commotion regarding flood levels, and the result was that gravel excavation now not only needs to result in improved nature, but also improved safety. The whole project also has to break even in budgetary terms, and that means too much gravel excavation.

The local people are strongly resisting the plan. Some people call it NIMBYism, but people are well within their rights when they oppose developments which will make their surroundings less attractive. The area will be exploited until 2022, and all this time we will be faced with extra noise and dust. Unique natural and historic sites will be lost. And then the new nature will have to develop. But what will have been achieved?

'The Netherlands is a small country: think big.' Rijkswaterstaat is one of the institutions charged with carrying out this slogan. These institutions are supposed to form a link between the authorities they represent and the people whom they serve. But there is a lot of room for improvement here. If I could give a tip to Rijkswaterstaat, I'd say: Listen openly and honestly to what people have to say, and give an adequate response. And above all, don't deny your own professional ethical standard when the government gives you an unworkable order."

Mr Peeters, of the Vereniging Federatief Verband tegen Ontgrindingen in Born

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1 Amsterdam, city built on water. **2** Public participation around the digital "Design table" **3** The Spieringplaat in the Noordwaard **4** Gravel extraction is combined with nature development in the Grensmaas project.

ENVIRONMENTAL QUALITY

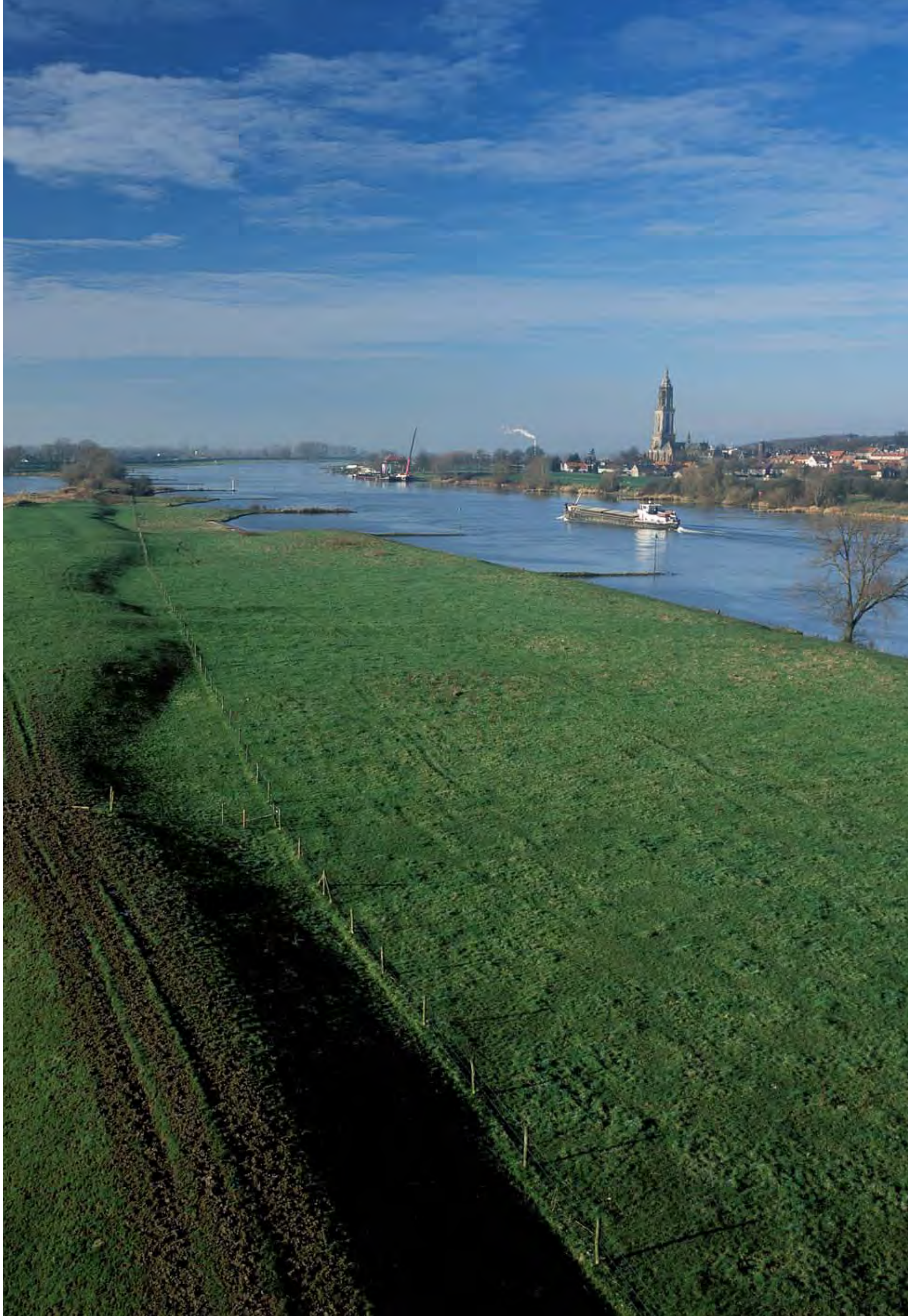
Rijkswaterstaat is responsible for keeping our feet dry and ensuring that we have sufficient good-quality water. But there are other interests which play a part in the river area. People want to use the area for living, working, recreation and transport. The landscape needs to be attractive, and valuable features preserved. Moreover, society sees a need to keep open options for possible new ways of using the area, or new values we may put on it, in the future. These qualities can be summed up in the term 'spatial quality'.

Measures concerning water management frequently have to contribute to an improvement in environmental quality as well. The projects for creating space for the river even state the improvement of environmental quality as their second aim. But who decides what constitutes an improvement? No legal norms exist for environmental quality, everyone has their own opinion. This puts a special onus on the development process.

In its Spatial Policy Document, the government set out general guidelines for environmental quality in various parts of the country, including the riverside area. But the environmental quality depends strongly on local circumstances, such as the presence of an important wildlife area, a harbour or a bridge. The plan for improving environmental quality will always have to be tailored to suit each location. Local residents, businesses and administrators have a big say in the drawing up of plans, since after all, it concerns their direct living space.

Environmental quality is a broad concept. To make it more tangible, the concept has been broken down into usage quality, experiential quality and future value:

- The usage quality is rated high if the space can be used in a safe and practical way for different functions and if these functions do not interfere with each other, but complement each other.
- The experiential quality is rated high if the living environment is recognisable, varied, with spatial variation on a human scale, contains distinguishing characteristics (identity) and if the origins of cultural history and beauty can be easily read.



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- The future value is rated high if the area is suitable for new forms of use and can have a new cultural and economic purpose. Sustainability, biodiversity, sturdiness, adaptability and flexibility in time are all important qualities for a high future value.

Any measures which are taken will lead to improvement of the environmental quality only if these three qualities are in equilibrium.

A DIFFERENT APPROACH TO FLOOD RISKS

The standards that apply to dykes are based on the situation as it used to be about fifty years ago. In the meantime, the population of the Netherlands has increased significantly, and the economic value has risen likewise. If there were to be a major flood now, the consequences would be much greater than the situation planned for by the Delta Commission of that time. The Ministry of Transport, Public Works and Water Management has initiated a nationwide discussion to examine and evaluate the protection against flooding. In this discussion, the following issues are dealt with:

Do citizens, businesses and administrators have enough awareness of the risk of flooding?

Flooding is one of the risks we face living in the Netherlands. Dutch people themselves seem to be less well aware of the risks posed by flood levels than the risks posed by e.g. traffic accidents, smoking or air travel. Flood consciousness is necessary for people to understand the sweeping measures which need to be taken in order to guarantee protection against flooding. Flood consciousness is also vital if we are to engage in the discussion concerning self-preservation measures during times of flooding and the insurability of flood damage. For administrators, a raised level of flood consciousness leads to an awareness of the need for drawing

5 The Nederrijn near Rhenen **6** A mother taking her two children to school, as the summer dyke at the floodplain is no longer flooded. The normal access road is still underwater. When the water level rises above the summer dyke this family lives on an island. **7** Floating cottages in the recreation lake the Gouden Ham (Maasbommel) up plans for emergencies, and holding regular drills. The government is stimulating high-water consciousness, for example through its advertising campaign 'Nederland leeft met Water' (The Netherlands: living with water), (www.nederlandleeftmetwater.nl), and by distributing information such as maps showing the areas which are at risk from flooding (www.risicokaart.nl).

Should densely-populated urban areas with a great deal of valuable property be better protected than rural areas with few inhabitants?
The current norms already take differences in population density and economic value into account. This is one of the reasons why the area of the Rhine-Meuse estuary in the Randstad has a higher norm than the Meuse in Limburg and the Rhine tributaries in Gelderland and Overijssel. The question is, should more differences in norms be implemented, depending on the value of the area behind the dyke?

Should flood protection be supplemented by damage-limitation measures for if things should go wrong despite protection?
The safety policy for flooding has a strong emphasis on flood prevention using dykes and other flood barriers. But there is always the possibility that things will go wrong, and in such a case, prompt action is essential in order to keep potential damage to a minimum: evacuation of people and livestock, speedy reparation of the dyke, opening of crisis centres, and clearing up the mess once the water has subsided. All this requires good preparation, for example by having emergency plans ready for use, and holding regular emergency drills. Other measures can also help restrict damage, such as building houses on raised plots and constructing partition dykes to prevent the water flooding a large area. In 2006, the Flood Management Task Force was set up, whose job is to improve organisational preparation regarding flooding. The major points for improvement are: cooperation between authorities, harmonising strategies and emergency plans from different parties, and holding regular drills.

There are many other ways in which the Netherlands can reduce its vulnerability to flooding: one example of this is taking water into account at the spatial planning stage when land-use decisions are made. Together with other authorities, scientists and interest groups, Rijkswaterstaat is exploring the possibility of a 'waterproof' spatial planning policy. In the 'Adaptation Programme Space and Climate' (ARK), four ministries are working together to increase public awareness regarding climate change, research into the effects of climate change, and new solutions.

8

8 Dyke along the River Waal near Ewijk

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treaties, policy documents, reports		events
	1798	establishment of Rijkswaterstaat
	1870	regulation of the Rhine, 1st phase
	1874	completion Nieuwe Merwede
	1890	regulation of the Rhine, 2nd phase
	1904	completion Bergse Maas
Rivers Act	1908	
	1916	flooding of Zuyder Zee area
	1916	completion regulation of the Waal
	1926	flooding Rhine and Meuse
	1928	completion regulation of the IJssel
	1929	canalisation of the Meuse
	1932	closing-off of the Zuyder Zee
	1934	completion regulation of the Nederrijn/Pannerdensch Kanaal
	1950	International Commission for the Protection of the Rhine
	1952	completion Amsterdam-Rijnkanaal
	1953	flood disaster Zeeland/Zuid-Holland/Brabant
	1956	first normative flow level established
Delta Plan	1957	
Delta Act comes into force	1958	first phase of Delta works operational: Hollansche IJssel storm surge barrier
	1962	International Commission for the Protection of the Meuse
first Water Management policy document	1968	
Pollution of Surface Waters Act comes into force	1970	
	1970	completion canalisation of the Rhine
	1970	Commission internationale de l`Hydrologie du bassin du Rhin (CHR)
Limits to Growth (Club of Rome)	1972	
	1977	river dykes commission (Becht)
Rhine Salt Treaty	1976	extremely dry summer
	1977	start improvements to river dykes
	1980	further regulation of the Beneden Waal
Integrated Regional Water Management regulation operational (until 1992)	1982	
second Water Management policy document	1984	
Dealing with Water	1985	
	1986	Rhine environmental disaster (Sandoz, Basel)
	1986	start construction of dredge spoils site 'de Slufter'
	1986	introduction of six-barge tugs on the Rhine
Rhine action programme	1987	
Ooievaar Plan	1987	
third Water Management policy document	1989	
	1989	rivers nature development project: Duursche Waarden
	1989	start Waal shipping programme
National environmental policy plan-plus	1990	
Nature policy plan, introduction Ecological Main Structure of the Netherlands	1991	
Fourth policy document on Spatial Policy Extra	1991	
Further elaboration of the river area (NURG-programme)	1991	
	1991	start modernisation of the Meuse-route
Blueprint for green space	1992	
Living rivers	1992	
Green for Gravel	1992	
Water Board Act	1992	inauguration Committee for reviewing principles of river dyke reinforcement (Boertien I)
first IPCC report on climate change	1992	
second National Environmental Policy Plan	1993	Meuse floods
	1993	inauguration Committee Meuse flood disaster (Boertien II)
Policy Document Water evaluation	1994	
	1994	formal establishment Biesbosch National Park
	1995	Rhine and Meuse floods
	1995	start of Meuse Works
Flood protection act	1996	
Policy 'Room for the River'	1996	
A Future for Water, final report Water System Studies	1996	
policy document Integral Study of the Rhine branches (IVR)	1996	
	1997	completion of the Maeslant Barrier
	1997	Storm Surge Barrier in the Nieuwe Waterweg operational
policy document Active Riverbed Management	1997	
International Rhine Flood Action Plan	1997	
fourth Policy Document on Water Management	1998	
International Meuse Flood Action Plan	1998	
	1999	completion of Ketelmeer dredge spoils site
	2000	completion of river dyke reinforcements
Groundplan Zandmaas/Maasroute established	2002	
Grensmaasproject established	2005	Levees in Limburg included in the Flood protection act
Major Rivers policy line	2006	
Spational Planning Key Decision 'Room for the River' established	2006	